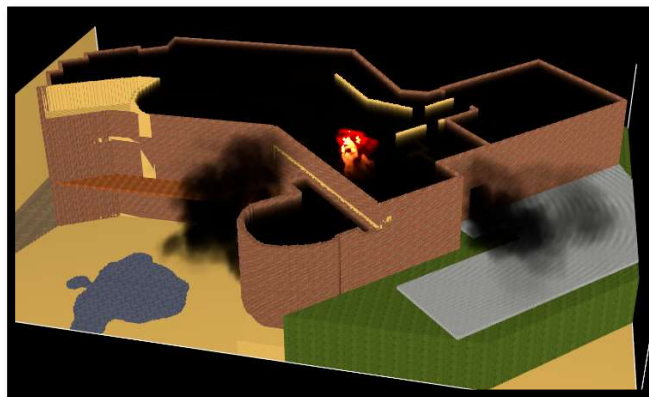


# Analysis of the Line of Duty Death of Firefighter Nathan Flynn Utilizing Fire Dynamics Simulator, Fire Testing and Electronic Data Sources

7005 Woodscape Drive, Howard County, MD

Incident Date: July 23, 2018



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**CERTIFIED FIRE INVESTIGATOR PROGRAM RESEARCH**

**ATF BALTIMORE FIELD DIVISION**

## ABSTRACT

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The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Baltimore Field Division provided technical assistance to the Howard County Maryland Office of the Fire Marshal at the scene of a large residential fire located at 7005 Woodscape Drive on the morning of July 23, 2018. A fire occurred in the 8,400 square foot (sq. ft.) single family residence that resulted in the Line of Duty Death (LODD) of Firefighter (FF) Nathan Flynn. Investigators also requested assistance from the ATF Fire Research Laboratory (FRL). ATF personnel utilized engineering analysis methods including field fire testing, large-scale laboratory fire testing, advanced computer fire modeling and electronic data sources to assist with determining the origin and cause of the fire, the route of fire spread throughout the structure and the events that led to the firefighter MAYDAY and LODD.

The fire was classified as “Natural” by the investigative team, resulting from a nearby lightning strike to a large tree. Associated energy from the lightning strike followed a path from the tree, through soil, to a nearby underground propane fuel storage tank. The propane storage tank supplied the residence through an underground copper supply line that transitioned to metallic Corrugated Stainless Steel Tubing (CSST) that ran through the crawl space beneath the living room. The lightning strike energized the propane distribution system, causing the CSST in the crawl space to arc to a nearby grounded object in the crawl space. This high-temperature arcing event resulted in a small hole forming in the CSST gas line, which allowed propane gas to leak from the hole and also likely ignited the escaping gas at the same time. This event created a small (6-12 inch), sustained propane diffusion flame along the ceiling of the crawl space proximal to the wooden floor joists and other combustible items stored in that area. The residents called 911 approximately 30 minutes after the lightning strike when they noticed smoke in their living room. Exactly 60 minutes after the lightning strike, Firefighter Nathan Flynn called a MAYDAY after he fell through the living room floor into the burning crawl space below. A similar sequence of events resulted in the LODD of Captain Joshua Laird in Ijamsville, Maryland three years later. ATF also provided technical assistance at that Ijamsville, MD LODD fire scene and concluded that lightning induced failure of CSST resulted in a basement fire, floor collapse and subsequent MAYDAY/LODD of Captain Laird. A fact-based comparison of both LODD incidents is included in the conclusion of this report to highlight the common elements that resulted from both ATF fire origin and cause investigations.

The purpose of the report and associated video timeline was to analyze the sequence of fire events that ultimately led to the LODD of Firefighter Nathan Flynn. Forensic data was then compiled to generate a comprehensive video fire timeline, including: forensic lightning strike data, 911 calls, fire dispatch/operations audio, MAYDAY audio, forensic Apple Watch GPS/movement/biometric data, electronic SCBA data, portable radio movement/channel data, advanced computer fire modeling, field fire testing, large-scale fire testing, three-dimensional building measurement scans, drone footage and incident photographs/video. Fire Dynamics Simulator (FDS), a Computational Fluid Dynamics (CFD) computer fire modeling program, was utilized to gain a better understanding of the flow of heat, smoke and fire gases throughout the residence.<sup>1</sup>

There was no single root cause event that led to the LODD of firefighter Nathan Flynn, rather the following five conclusions were developed as a result of the fire development analysis:

**1. Extremely large volume of the residence allowed for a well-developed fire, despite light smoke showing on the exterior:**

The residence at 7005 Woodscape Drive consisted of approximately 8,400 square feet of open living space that spanned three continuous (non-compartmented) levels. At this fire, the volume of the house was almost three times larger than what many firefighters routinely encounter and the average square footage of residences in the United States continue to increase. Generally, as a dwelling fills with dense smoke, the fire will become ventilation limited and the heat release rate (fire size) will only decrease once the smoke layer banks down below the level of the flames. Under similar circumstances, a fire that has three times more air (enclosure volume) available will be allowed to release three times more energy prior to becoming ventilation limited. This increased fire growth, fire duration and total heat released creates additional fire suppression challenges and also increases the potential for structural collapse. A fire that is allowed to burn freely for a longer period prior to becoming ventilation limited, will also consume more fuel. This extended burn period can result in greater consumption of combustible structural members, which further increases the risk of structural collapse. Firefighters can use the relative height of the smoke layer to assist in locating the level of the seat of the fire. It is often safest to attack the fire from the same level of the flames, or a level below, where possible. In addition, personnel should also consider the level of the fire when determining how much oxygen may have been available to a fire prior to arrival. A basement fire that is open to the rest of the residence will have considerable more ventilation to support fire growth when compared to a fire on an upper floor that becomes ventilation limited much faster. Large volume structure fires are inherently challenging as they support higher fire heat release rates (increased fire size), increased total heat energy released, increased total mass loss/consumption of fuels (to include combustible structural components), and require greater suppression resources to absorb the additional energy being released.



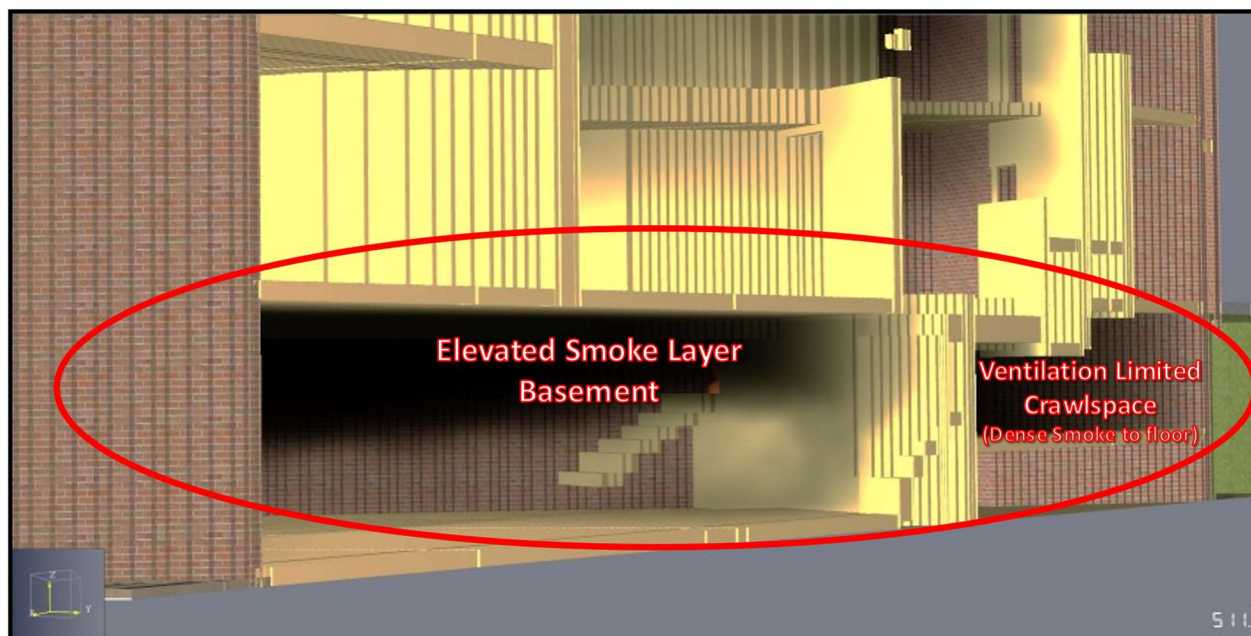


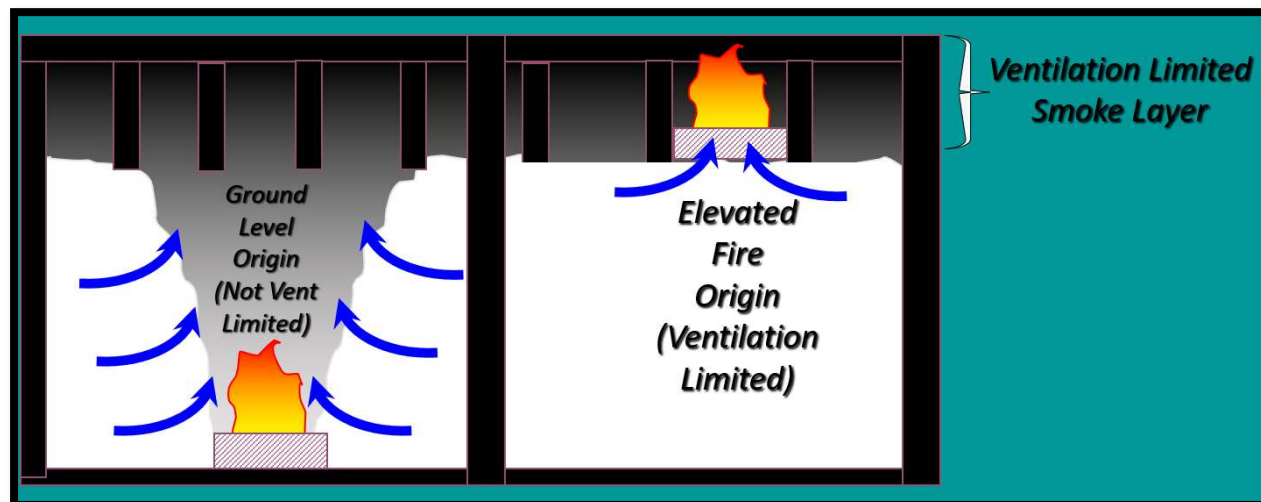
## **2. Elevated fire located in the basement crawl space created atypical smoke filling conditions in basement:**

The fire developed in an elevated crawl space located above the basement floor and resulted in atypical smoke conditions in the basement, including a light, elevated smoke layer in the basement and relatively dense smoke on the 1<sup>st</sup> and 2<sup>nd</sup> levels. The lack of thick, heated smoke in the basement resulted in crews believing the seat of the fire was located on the first level. When crews initially entered the first floor, they immediately identified heat and smoke signatures consistent with a basement fire below them. The crews then decided to reposition to the basement level, leaving the first floor mud room door open when they withdrew. The same crew then opened the basement door and identified smoke filling consistent with a fire above the basement level due to



relatively elevated “cold smoke” and minimal heat in the basement. The elevated crawl space opening was visually obstructed and the crews could not immediately locate the seat of fire, which was in the crawl space directly below the living room floor. Exterior crews then noticed flames extending through the living room floor above the crawl space and requested crews to reposition the hoseline back to the first floor entrance. The fire conditions observed were inconsistent with a fire in the basement and also inconsistent with a fire on the first level. In reality, the crews correctly identified conditions consistent with an elevated fire (in the elevated crawl space) that was in fact below the first floor and also above the basement level. It is important for the fire service to understand elevated fire dynamics as CSST is frequently located in the interstitial space between the basement and first floor and the flames can extend from the CSST arc hole location to the combustible structure of the building. Elevated fires are unique in that they can become oxygen deficient (ventilation limited) and prior to the smoke layer reaching the level of the floor. The relatively complex fire dynamics associated with elevated fires are rarely taught to the fire service/fire investigation community. Firefighters should ensure that the basement is completely free of smoke and fire, including at the basement ceiling level where CSST may be routed, as part of fire scene size-up operations.





Elevated fires are unique as they become ventilation limited prior to the smoke layer reaching the level of the floor. The fire developed in an elevated crawl space located above the basement floor and resulted in atypical smoke conditions in the basement, including a light, elevated smoke layer in the basement and relatively dense smoke on the 1<sup>st</sup> and 2<sup>nd</sup> levels. The lack of thick, heated smoke in the basement resulted in crews believing the seat of the fire was located on the first level.

3. A ventilation flow path existed from basement door (inlet), through the hole in the crawl space and out first floor mud room door (outlet). This flow path created untenable conditions on the first floor during the MAYDAY:

The effects of a ventilation unidirectional flow path that existed from the basement door (inlet), through the burning crawl space and up through the living room/mud room door caused firefighters to first see flames on the first floor and incorrectly believe the fire originated and was located in the first floor living room. Firefighter Flynn attempted to suppress the flames he saw in the living room when he fell from the first floor into the burning crawl space below. This same ventilation exhaust flow path prevented rescue of Firefighter Flynn from the first floor during the MAYDAY as heated fire exhaust gases from the free-burning crawl space vented upwards through the hole and created untenable conditions for firefighters on the first floor. This unidirectional flow path also prevented a successful rescue from above the hole. Firefighters then realized the only way to facilitate the rescue was to attack the flames in the crawl space from the basement level along the inlet of the ventilation flow path. Rescue crews encountered flames throughout the crawl space as they advanced towards the sound of Firefighter Flynn's alarming SCBA. Computer fire modeling indicated high velocity, unidirectional smoke exhausting from the mud room during this time. Crews on scene stated that they believed the mud room was approaching flashover conditions during MAYDAY/RIT operations in the basement. This observation was supported by computer fire modeling simulations as well as video captured during the fire.



**Photo of exhaust flow path at the Upper Side C Entrance immediately before and immediately after the floor collapse and MAYDAY of FF Flynn.**

#### **4. Corrugated Stainless Steel Tubing (CSST) location and associated structural collapse:**

Firefighter Flynn fell through a hole in the living room floor downwards into the burning crawl space below. The wood floor joists and wood sheathing that supported the flooring system burned away in the area of the CSST arc hole and resulted in structural collapse of the massive tile flooring system into the burning crawl space. In this particular incident, the flooring system above the burning crawlspace was comprised of several layers of wood sheathing, cement board and thick non-combustible Italian tile, representing a significant dead loading of the flooring system. The pressurized propane gas that flowed through the CSST arc hole ignited and burned for approximately 60 minutes, consuming the combustible structural floor members prior to collapse of the floor into the burning crawl space. Fire testing indicated that the relatively massive, non-combustible top layers of the flooring system (tile and cement board) also masked the heat signatures one might expect from a fully-involved crawl space fire and structurally-compromised flooring support system below. Due to the common placement of gas-fueled appliances in the basement level and throughout the first floor, including the kitchen and living room, CSST is frequently routed through the combustible structural void space between the basement ceiling and the first floor. In addition, unlike traditional iron fuel gas pipe, multiple parallel CSST lines are routed through interstitial spaces with one CSST branch line supplying each appliance. This equates to significantly more installed linear feet of CSST gas piping as compared to similar iron pipe fuel gas installations. In addition, multiple CSST arc holes can result from a single lightning event, which can result in multiple concurrent fires located throughout a structure. The location of the CSST gas lines proximal to combustible structural members can support sustained burning of these members, which can lead to structural compromise and collapse from the first floor into the burning basement. The collapse risk is compounded by the fact CSST fires can remain concealed in the structural void space above the basement and flames are often first visible at the first floor level, causing firefighters to operate above the seat of the fire with weakened structural components below them. Thermal imaging views of the floor system above the seat of the fire appeared “normal” and there were no obvious heat signatures consistent with a well-developed fire in the crawl space below. There are no reliable indicators of pending structural collapse for firefighters and Firefighter Flynn was likely unaware of the fire in the crawl space below him. In the LODD incident involving Captain Laird approximately three years later, multiple CSST arc holes occurred underneath a tiled kitchen floor that was also

thermally thick. The tiled floor collapsed into the burning basement as Captain Laird attempted to suppress flames on the first floor. Particularly when a lightning strike is suspected, firefighters should gain access and rule-out fire spread in concealed spaces containing combustible structural members on all levels of the residence, with particular attention paid to the interstitial space located between the basement and the first floor. Firefighters should also be aware that CSST arc holes and subsequent gas ignition can occur due to arcing contact of the CSST with energized electrical branch circuits, unrelated to lightning exposure. Not all CSST related fires result from lightning.



**ATF Fire Research Laboratory testing of a CSST gas line, ignition of the escaping gas and flame spread across the structural components of the flooring system from 7005 Woodscape Drive.**





**Thermal imaging views of the floor system above the seat of the fire appeared “normal” and there were no obvious heat signatures consistent with a well-developed fire in the crawl space below.**

#### **5. Additional Lightning Induced Corrugated Stainless Steel Tubing (CSST) LODD Incident:**

On August 11, 2021, approximately three years after the LODD of Firefighter Nathan Flynn, Captain Joshua Laird (Frederick County Maryland Fire and Rescue) died while battling a fire in a large residential structure caused by lightning induced failure of CSST in the basement. Captain Laird called a MAYDAY and was killed after falling through a hole from the first floor into the burning basement below, where the fire originated. Flames were visible on the first floor and Captain Laird was unaware of the fire in the basement below him. The non-combustible tiled floor, cement board and wood structural components collapsed and formed a hole above the general location of the CSST arc holes located between the wood basement floor trusses. The timeframe and common circumstances of both LODD incidents are astonishingly similar and warrant review to prevent future similar incidents. A detailed analysis of the fire development of the Ball Road LODD is outside the scope of this report, however multiple fact-based similarities between these incidents exist and highlight the importance of the conclusions developed in this report. The details about Captain Laird’s LODD incident were sourced from the publicly released “Frederick County After Action Report and Improvement Plan.”<sup>4</sup>

## KEYWORDS

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- Fire Dynamics Simulator (FDS)
- Computer Fire Modeling
- Firefighter Structural Collapse
- Basement Fire
- Firefighter Line of Duty Death (LODD)
- Firefighter MAYDAY
- Smart Watch/Apple Watch Data Recovery
- Self Contained Breathing Apparatus (SCBA) Data Recovery
- Lightning Detection Network
- Corrugated Stainless Steel Tubing (CSST)

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## INTRODUCTION

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Beginning at the fire scene on July 23, 2018, investigators from ATF, Howard County Office of the Fire Marshal, and the Office of the Maryland State Fire Marshal worked collectively to determine the origin and cause of this fire. As the primary federal resource tasked with fire origin and cause determination, ATF authored a detailed fire origin and cause report and conducted additional research, including a forensic fire timeline that detailed the sequence of events before, during and after Firefighter Flynn's MAYDAY. Fire Dynamics Simulator, a Computational Fluid Dynamics computer fire modeling program, was utilized in conjunction with laboratory fire testing to gain a better understanding of the flow of heat, smoke and fire gases throughout the structure and multiple modeling simulations of this fire are included in this video timeline.

This fire originated when a lightning induced arcing event created a small arc hole in the wall of Corrugated Stainless Steel Tubing, commonly abbreviated as CSST. The arcing event ignited the escaping propane and created a sustained gas flame along the ceiling of the crawl space near wood floor joists and other combustible storage items. Exactly 60 minutes after the lightning strike, Firefighter Nathan Flynn called a MAYDAY after he fell through the living room floor into the burning crawl space below.

Its relevant to note that approximately three years after this incident, Captain Joshua Laird of Frederick County Maryland, was also killed battling a fire in a large residential structure caused by lightning induced failure of CSST located in the basement of the residence. Both Firefighter Flynn and Captain Laird were suppressing flames on the first level when the floor beneath them collapsed, causing them to fall into the burning basement and crawl space below. The floor collapse occurred above the location of the CSST gas line and both firefighters immediately transmitted MAYDAY calls for assistance, however they were unable to self-extricate. The timeframe and common circumstances of both of these Line of Duty Death incidents are similar and warrant review to prevent future similar incidents.

This report and the associated video timeline analysis is the culmination of numerous data sources collected as part of the investigation process, including: forensic lightning strike data, 911 calls, fire dispatch/operations audio, MAYDAY audio, forensic Apple Watch GPS/movement/biometric data, electronic SCBA data, portable radio movement/channel data, advanced computer fire modeling, field fire testing, large-scale fire testing, three-dimensional building measurement scans, drone footage and incident photographs/video. This data was compiled, analyzed and shared under the scope of the ATF Certified Fire Investigator Training program, which tasks ATF Certified Fire Investigator candidates with conducting innovative research in the field of fire investigation, fire origin/cause, and fire dynamics. The results of this research are shared with the intent to educate and inform the fire investigation community and the fire service, with the hopes of preventing future similar incidents.



## METHODOLOGY

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### **Computer Fire Modeling**

Working closely with Howard County investigators, ATF created a computer representation of the approximately 8,400 square foot (sq. ft.) single family residence using Fire Dynamics Simulator (FDS). FDS is a computational fluid dynamics (CFD) modeling program developed by the National Institute of Standards and Technology (NIST). FDS utilizes mathematical calculations to predict the flow of heat, smoke and other byproducts of fire. PyroSim Results, a proprietary post-processing computer program produced by Thunderhead Engineering, was then utilized to visualize the mathematical output from FDS. The most current available versions of both programs were used, PyroSim 2022, FDS 6.7.1 and PyroSim Results 2022.<sup>1</sup> A three-dimensional representation of the residence was built for FDS using a combination of data sources, including 360° forensic laser scans, original construction and architectural plans, photographs and hand measurements.

The large single-family residence consisted of approximately 7,300 finished sq. ft. above grade with an additional 1,100 sq. ft. of finished basement.<sup>2</sup> The fire was determined to have originated in an unfinished crawl space that opened directly to a Butler's Kitchen and the rest of the finished basement. A door was installed between the Butler's Kitchen and the unfinished basement, however it was constantly left open to allow a dehumidifier to operate. According to the architects, the residence was particularly designed to host large guest parties and featured a modern open floor plan design. Accordingly, there was no designed or inherent compartmentation that isolated the crawl space from the rest of the basement, the first floor and the bedrooms on the second level. As a result, smoke and heat were allowed to flow freely from the basement throughout all three levels of the residence. The large volume of the residence allowed significant fire growth prior to the smoke layer banking down from the upper levels to the level of the fire in the basement. The ventilation flow path consisted of smoke and heat traveling upwards from the basement to the 1<sup>st</sup> and 2<sup>nd</sup> levels, with relatively cooler fresh air traveling downwards from the upper levels towards to the basement. Accordingly, all three levels of the residence and the crawl space were included for fire modeling purposes.



**Figure 1. A front view (side A) of 7005 Woodscape Drive. The large single-family residence included approximately 8,400 square feet of finished living space.**



**Figure 2. An overall view of the North side (upper side C) of 7005 Woodscape Drive. Upper side C consisted of an at-grade entrance to a mud room/kitchen as well as a three-car garage. Firefighter Flynn utilized this upper side C entrance (indicated with a red circle) to initiate fire attack on the first floor just prior to falling into the burning crawl space below.**



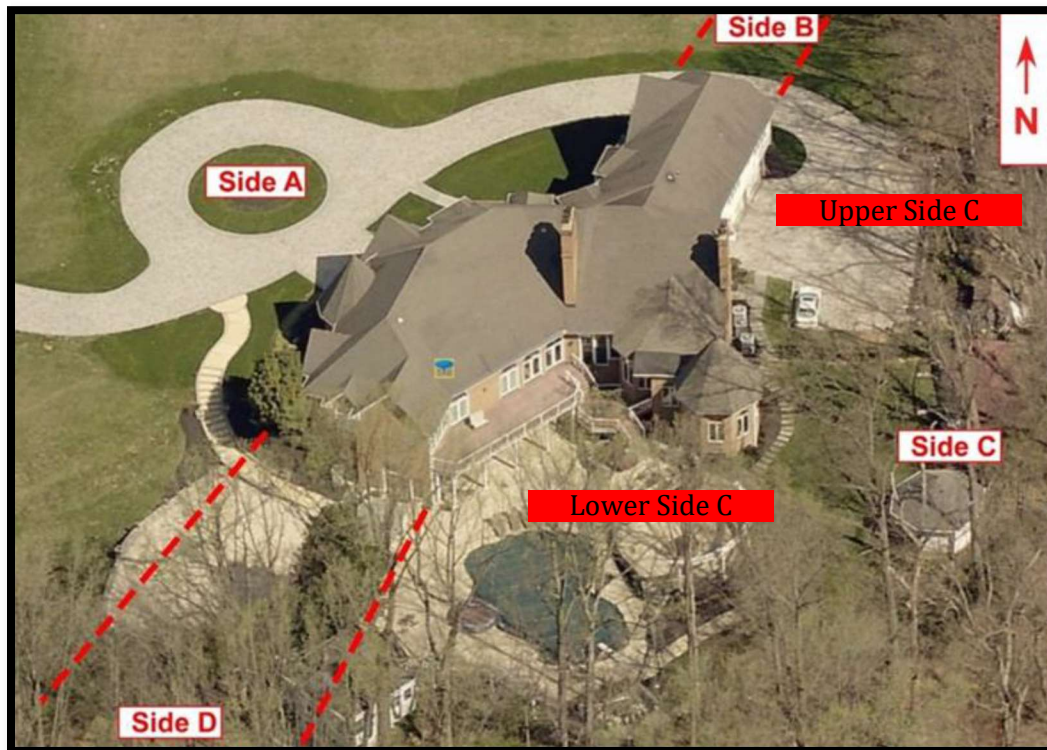


Figure 3. An overall aerial view of the rear (upper and lower side C) of 7005 Woodscape Drive. Sides B, C and D are also labeled.



Figure 4. An overall view of the lower side C (rear) of 7005 Woodscape Drive. Lower side C consisted of at-grade access to the basement, an elevated deck accessing the first floor and a large, in-ground swimming pool. The pool was utilized as a secondary water supply in addition to a municipal water supply relay from a distant hydrant. The at-grade entrance into the basement is circled.



**Figure 5. An overall view of the rear (lower side C) of 7005 Woodscape Drive during the fire incident. The fire originated in the crawl space, located directly underneath the living room/kitchen (circled in the photo). There was no exterior access to the crawl space, which was located mostly below grade.**



**Figure 6. An overall view of the south side (side D) of 7005 Woodscape Drive. At-grade access to the basement existed towards the rear and the terrain increased to the level of the first floor as one approached side A.**



FDS works by dividing a space into cubical “grid cells” for calculation purposes. FDS then computes various CFD calculations for each grid cell to predict the movement of mass, energy, momentum and other species throughout a three-dimensional space. Each modeling run of the Woodscape Drive model consisted of 10,585,080 total grid cells that were each 4 inch (10.16 cm) cubes. Figure 7 shows a view of the structure that was built in FDS and visually rendered in Pyrosim Results. Figure 8 shows a similar view with the 4 inch mesh overlaid. The model spanned a total elapsed time of 33.33 minutes, beginning before the 911 call and ending after Firefighter Flynn became trapped and the fire department Rapid Intervention Team (RIT) began their rescue efforts.

Due to the extremely large number of grid cells and extended duration of the model, Amazon Web Services (AWS) cloud computing was utilized by ATF. The FDS input file was uploaded to AWS, run concurrently on multiple processors and the results were then downloaded from AWS for analysis. This process was repeated for a total of five modeling computational runs. The model was then analyzed and synchronized with the real time scene audio and all other data sources throughout the duration of the fire.

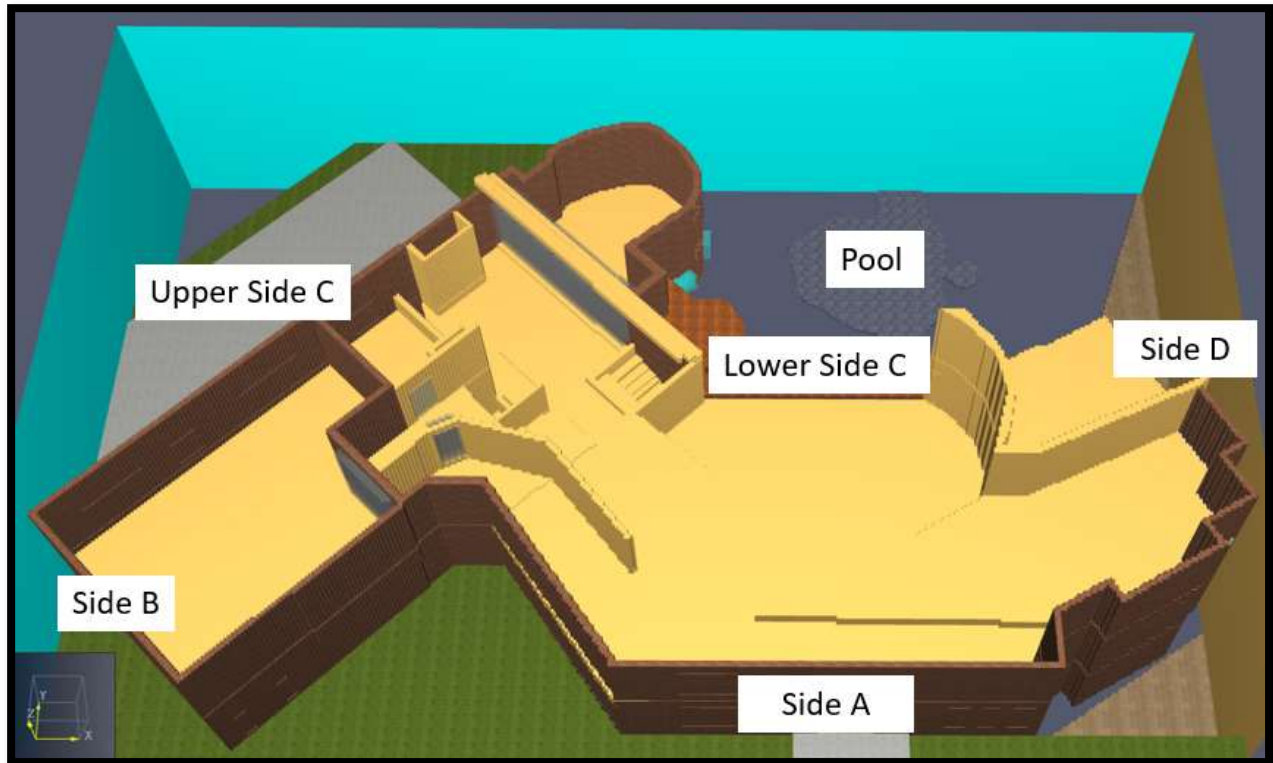


Figure 7. Aerial view of the FDS representation of 7005 Woodscape Drive indicating Sides A, B, C (upper and lower) and D.

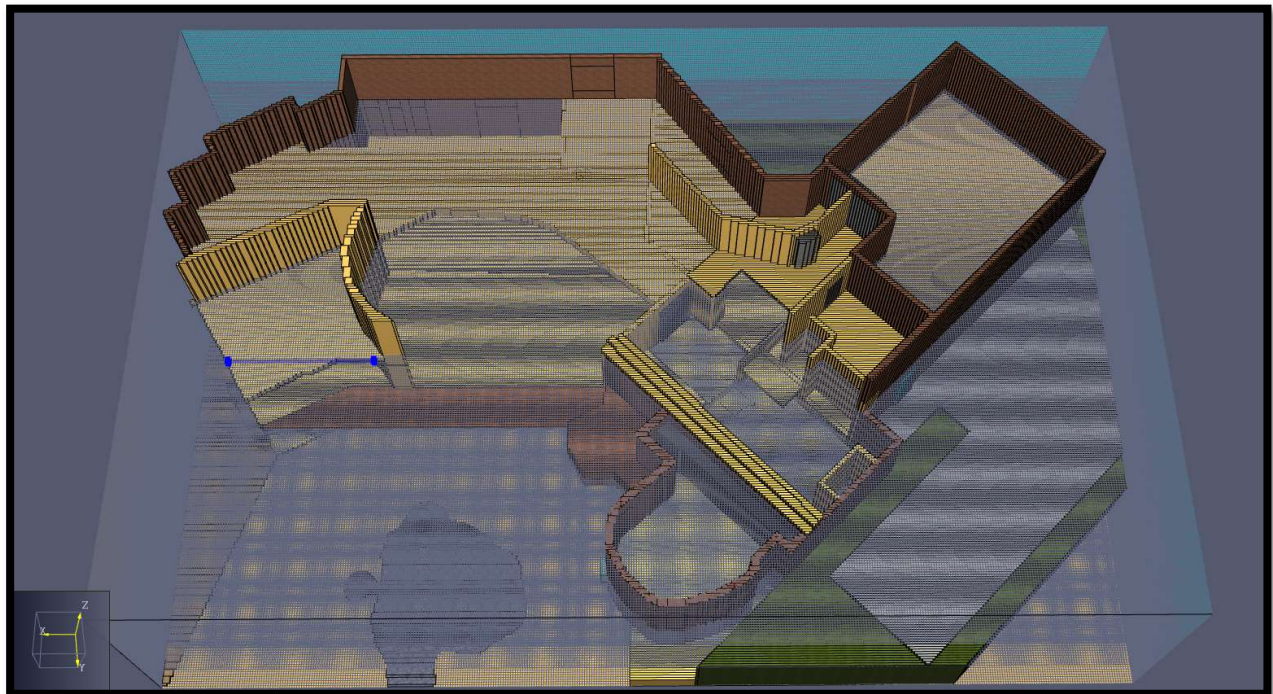


Figure 8. FDS representation of building with the 10,585,080 total grid cells and meshes included.

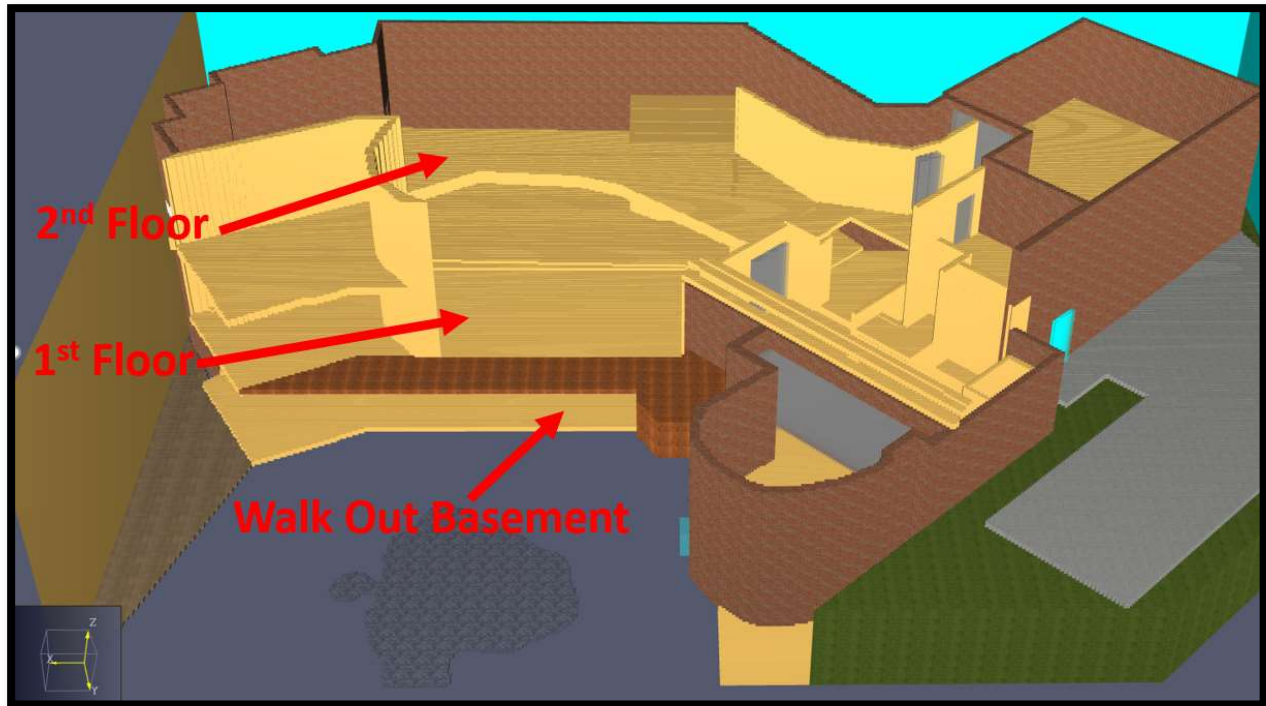


Figure 9. A rear view of 7005 Woodscape Drive indicating the basement, 1<sup>st</sup> and 2<sup>nd</sup> floors.

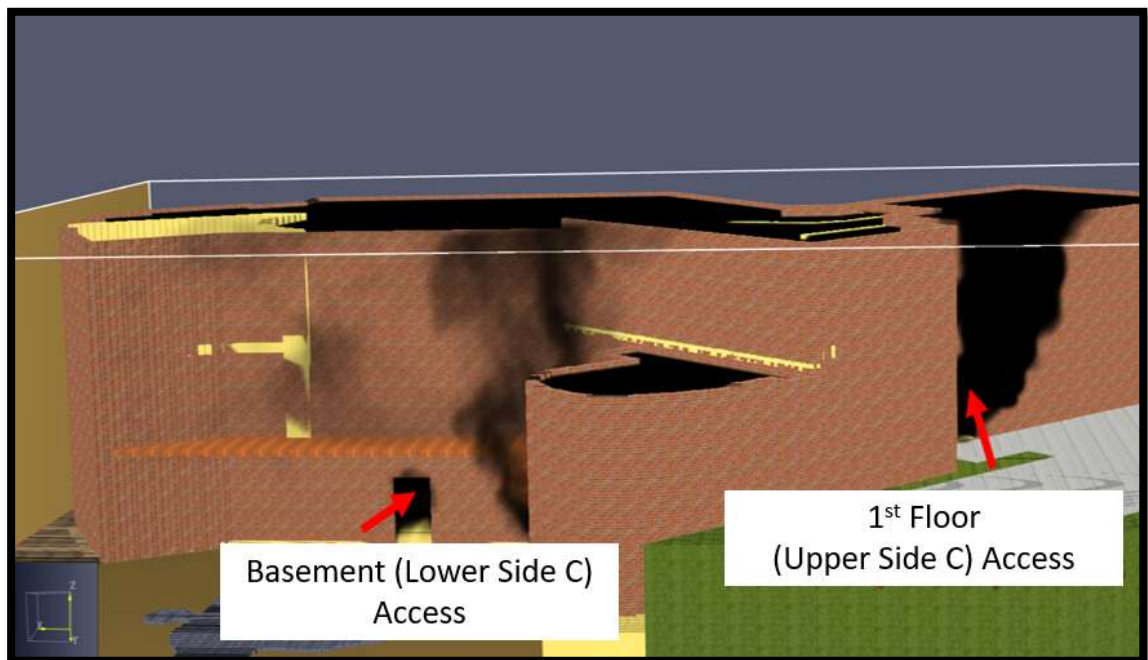
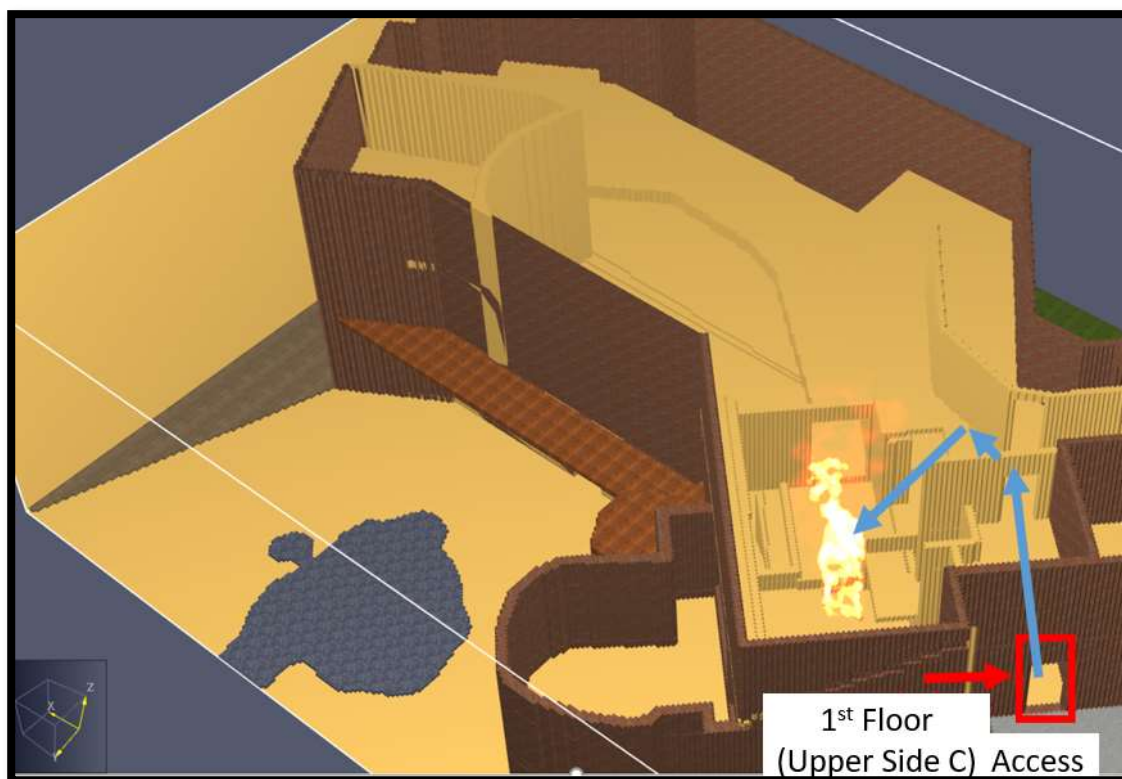


Figure 10. Pyrosim Results image detailing the two main access points utilized by firefighting crews. The lower side C basement at-grade entrance and the upper side C mud room entrance door leading to the 1<sup>st</sup> floor.





**Figure 11. Pyrosim Results image detailing flame extension through the hole from the crawl space to the first floor at the approximate time of FF Flynn’s MAYDAY. The modeled smoke has been disabled in this image. Blue arrows indicated general path of the hoseline advanced by Firefighter Flynn just prior to the MAYDAY.**

FDS has been validated to accurately predict the movement of heat and smoke throughout a compartment, however the capabilities of fire modeling are limited and no fire model is able to exactly replicate a particular fire scenario.<sup>3</sup> For this application, fire modeling was used to analyze smoke/heat filling, ventilation flow paths throughout the building and gain a better understanding of the fire dynamics associated with this LODD. In addition, FDS was utilized to illustrate the complex route of fire spread through the building as supported by photographs, fire patterns, field fire testing, full-scale fire testing, witness statements and firefighter interviews. FDS was not used to predict fire growth or spread from a CSST propane leak. A prescribed fire was used in the model based on fire growth observed from large-scale fire testing conducted by ATF in September 2018. Formation of the hole in the floor above the crawl space was specified by investigators based on firefighter observations, scene photographs/videos and observations from full-scale fire testing. FDS is not capable of predicting structural failure or collapse and it was not used for that application in this analysis.

The statements of each firefighter were reviewed and their individual actions (opening doors, closing doors, etc.) and observations (fire size, smoke conditions, etc.) were recorded on floor diagrams. The actions and observations of the firefighters were then associated with specific photographs, videos or times in the fireground audio to generate an overall event timeline. All events in the model are based on this master timeline of events. In addition, all photographs and videos were time stamped and synchronized with the model. The investigative



team was consulted throughout the development of the event timeline and the computer fire model to ensure accuracy. Ambient weather data was also incorporated into the fire model based on the weather conditions reported at the time of the fire.

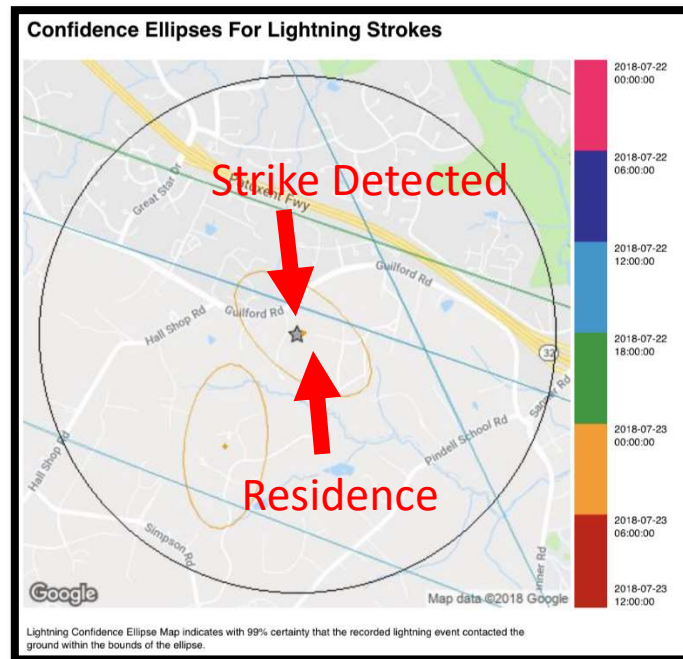
Based on specific requests from the investigative team, several additional alternative modeling runs were conducted and included in this analysis. The alternative modeling runs analyzed the elapsed time for the flames to become ventilation limited (oxygen deficient) if the same fire originated on the 1<sup>st</sup> and 2<sup>nd</sup> floors, rather than the basement. The fire modeling suggested that location of the fire within the open residence (basement vs. 1<sup>st</sup> floor vs. 2<sup>nd</sup> floor) has a significant impact on fire development and fire growth. The basement fire was allowed to continue to grow almost three times longer when compared to the same fire on located on the 2<sup>nd</sup> floor prior to consuming all available oxygen and becoming ventilation limited. Complete details of this analysis will be discussed later in this report.

### Timeline Data Sources

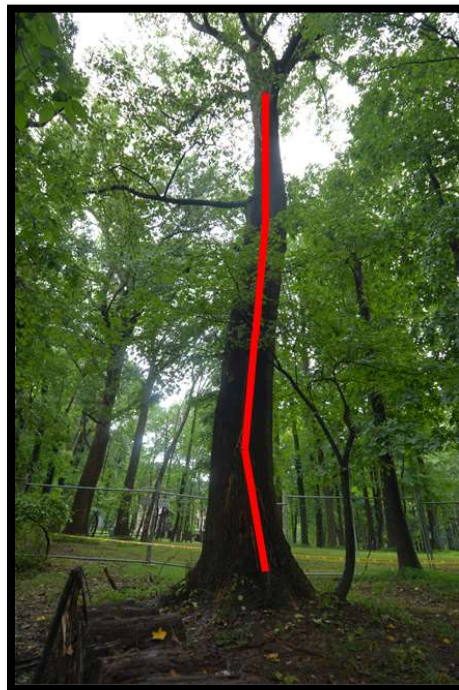
**StrikeNET Lightning Data:** StrikeNET is a proprietary third-party report that details all detected cloud-to-ground lightning strikes for a prescribed area during a prescribed period of time. The report details the location of detected lightning strikes, the exact time, location and peak current recorded. Analysis of the StrikeNET report relevant to this fire (shown in Figure 12) detailed a cloud-to-ground strike at a time consistent with witness statements. The location of the lightning strike was within the bounds of an ellipse with a stated certainty of 99% with an epicenter located less than 30 feet from the residence, as identified by the geographical coordinates. This particular strike registered a peak current significantly higher than that of other proximal lightning strikes and corresponded to physical damage to a large tree near the residence (see Figure 14). Lightning induced CSST arc hole formation and the potential for sustained flaming combustion will be discussed in further detail later in subsequent sections.

Lightning Strikes					
Date	Time (EDT)	Peak Current (kA)	Distance from Center (mi/ft)	Latitude	Longitude
Jul 23, 2018	01:20:48	-64	0/0	39.18622	-76.91583
Jul 23, 2018	01:21:22	-15.4	0.5/0.8	39.18622	-76.92142
Jul 22, 2018	14:45:59	-4.6	8.7/14	39.13898	-76.76613
Jul 22, 2018	17:59:52	-19.6	13.9/22.4	39.01959	-76.76993
Jul 22, 2018	22:04:56	-6.4	15.4/24.8	39.27813	-77.17806

**Figure 12. StrikeNET table listing all detected cloud-to-ground lightning strikes proximal to 7005 Woodscape Drive just prior to the fire. The strike that occurred at 01:20:48 EDT (circled) had a significantly higher recorded peak current and matched the exact GPS location of the residence. Physical damage to a nearby tree as well as witness statements also corroborated this data.**



**Figure 13. StrikeNET ellipse map detailing location of 7005 Woodscape Drive, the nearby detected strike (star) and the confidence ellipse detailing with 99% certainty that the strike occurred in the bounds of the ellipse. The location of the residence is represented as the green star.**



**Figure 14. Photograph depicting splitting to the trunk of a large tree located proximal to 7005 Woodscape Drive. The red lines depict the lightning induced damage. The soil between this tree and an underground propane storage tank was also displaced, forming a shallow trough in the earth.**

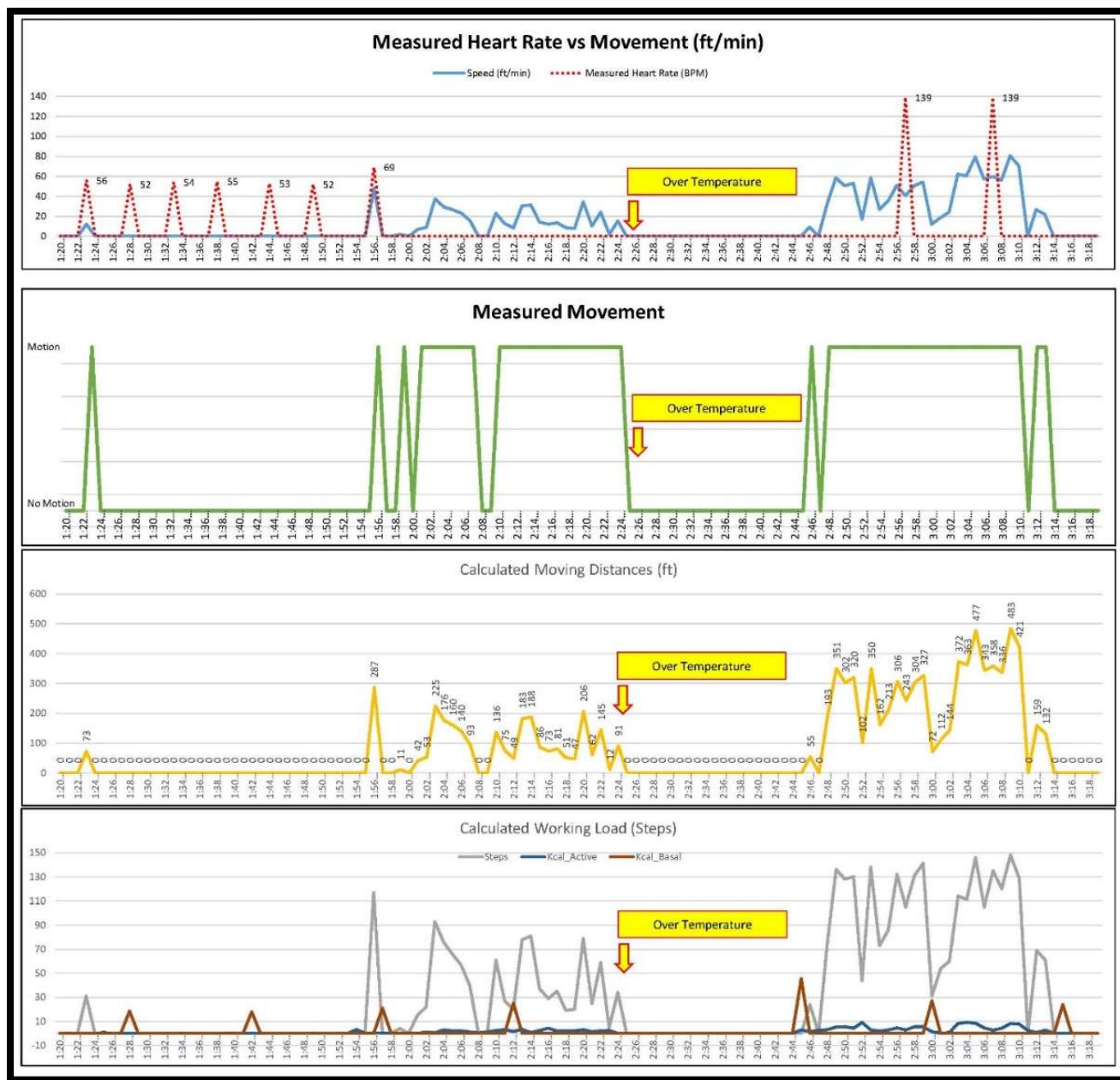


**Figure 15. Access cover to the underground propane storage tank proximal to the large tree with lightning damage. Copper Propane supply piping ran underground from this tank to where it entered the crawl space through the exterior upper side C wall, roughly following the red line in the photo. The propane supply piping then transitioned to corrugated stainless steel tubing (CSST) after entering the crawl space. A small hole caused by arcing was located in the CSST. No evidence of CSST bonding (grounding) was observed, including the service entrance and CSST supply manifold.**

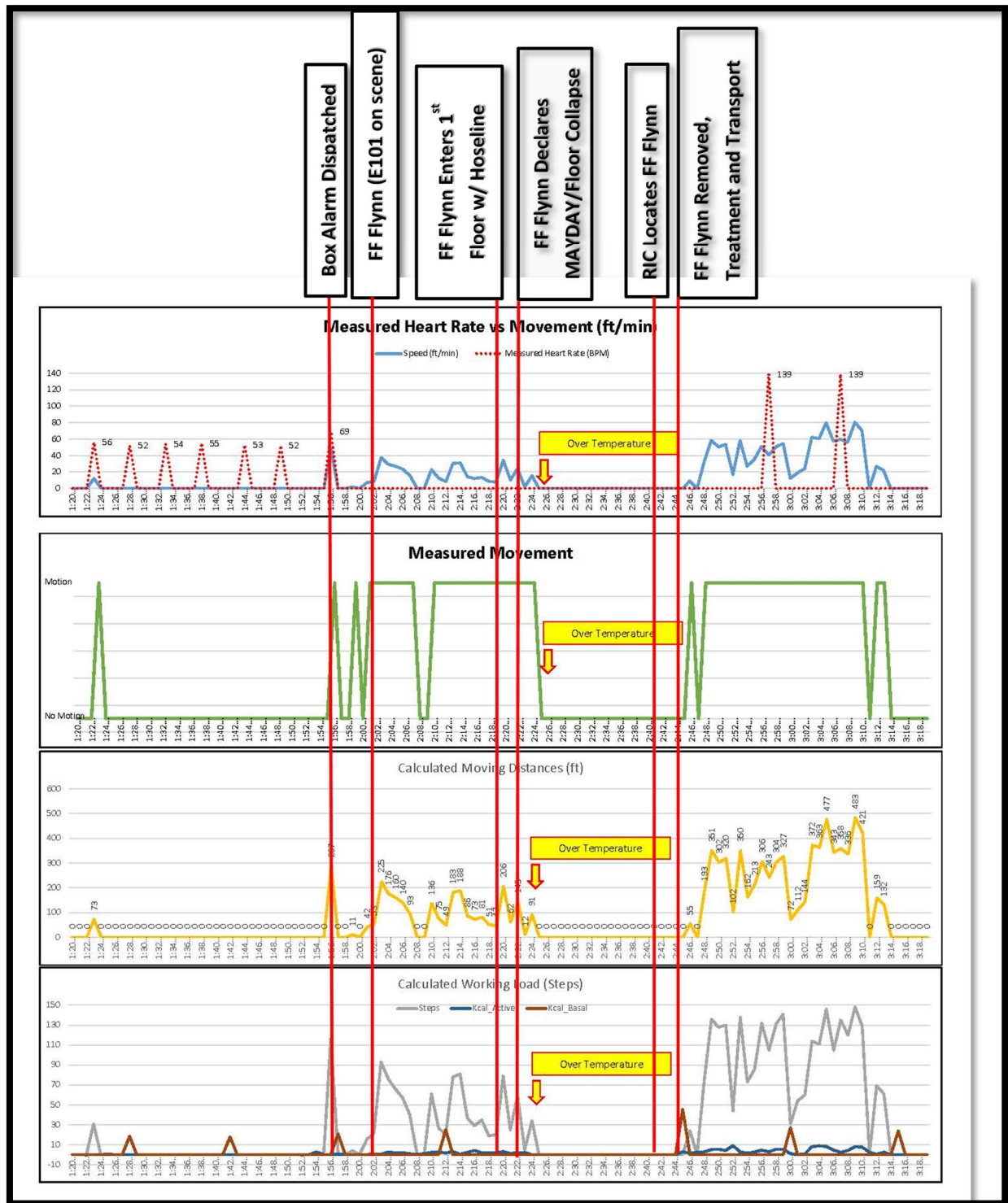
**Apple Watch:** Smartwatches, in particular Apple brand smartwatches, continually sense and record valuable forensic data including GPS location and speed, movement, heart rate and other biometric data. This data can be easily shared from any connected iPhone at a fire scene without conducting a physical download of the Apple watch. This data can be used to establish an event timeline and corroborate information provided by witnesses. Firefighter Flynn wore an Apple Watch that recorded numerous forms of data before, during, and after the fire. This data was forensically exported from the device, then graphed and analyzed by ATF Engineers. By analyzing biometric and movement data recorded by the watch, investigators were able to determine exactly when Firefighter Flynn was alerted to the fire call (while sleeping), estimated movement/distance traveled at the fire scene, Firefighter Flynn's heart rate data at various points throughout the incident, and watch over temperature conditions. Figure 16(a) serves as a visual representation of the Apple Watch biometric and over-temperature data and Figure 16(b) contains the same Apple Watch data with event timestamps overlaid. The Apple Watch over temperature event occurred just after Firefighter Flynn fell into the crawl space and declared



a MAYDAY. The Apple Watch was unable to record additional data during the over temperature fault, however data recording resumed after Firefighter Flynn was removed from the crawl space by the RIT members and the ambient temperature decreased. The movement and temperature data recorded by the Apple Watch was consistent with over temperature and movement data also recorded by Firefighter Flynn's Self-Contained Breathing Apparatus (SCBA) and portable radio during the same timeframe.



**Figure 16(a).** Visual representation of data recovered from Firefighter Flynn's Apple Watch including movement, heart rate, estimated distance and over temperature. This data was compared to other forensic data recovered from the SCBA and portable radio to gain a better understanding of Firefighter Flynn's movement both before and after the MAYDAY.

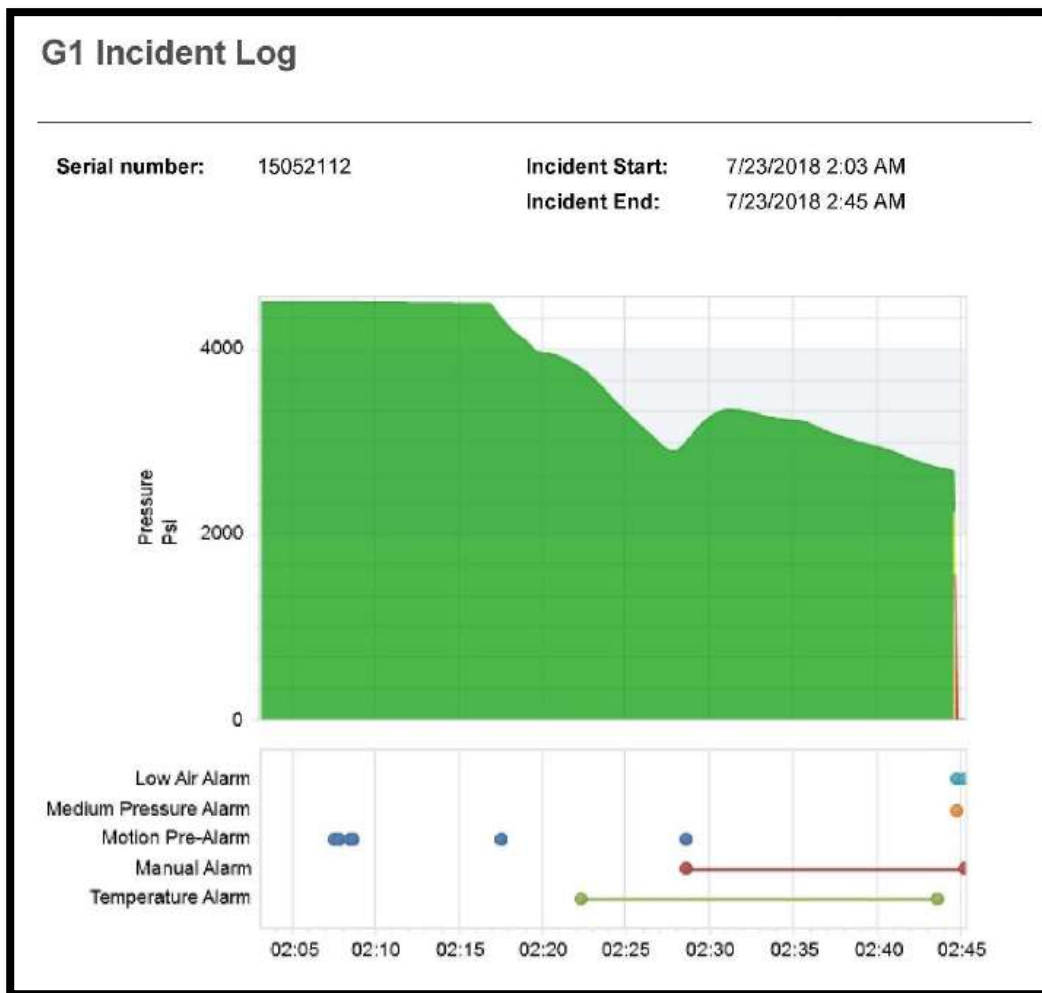


**Figure 16(b). Visual representation of data recovered from Firefighter Flynn’s Apple Watch with event timestamps overlayed. The Apple Watch was unable to record additional data during the over temperature fault, however data recording resumed after Firefighter Flynn was removed from the crawl space by the RIT members and the ambient temperature decreased.**

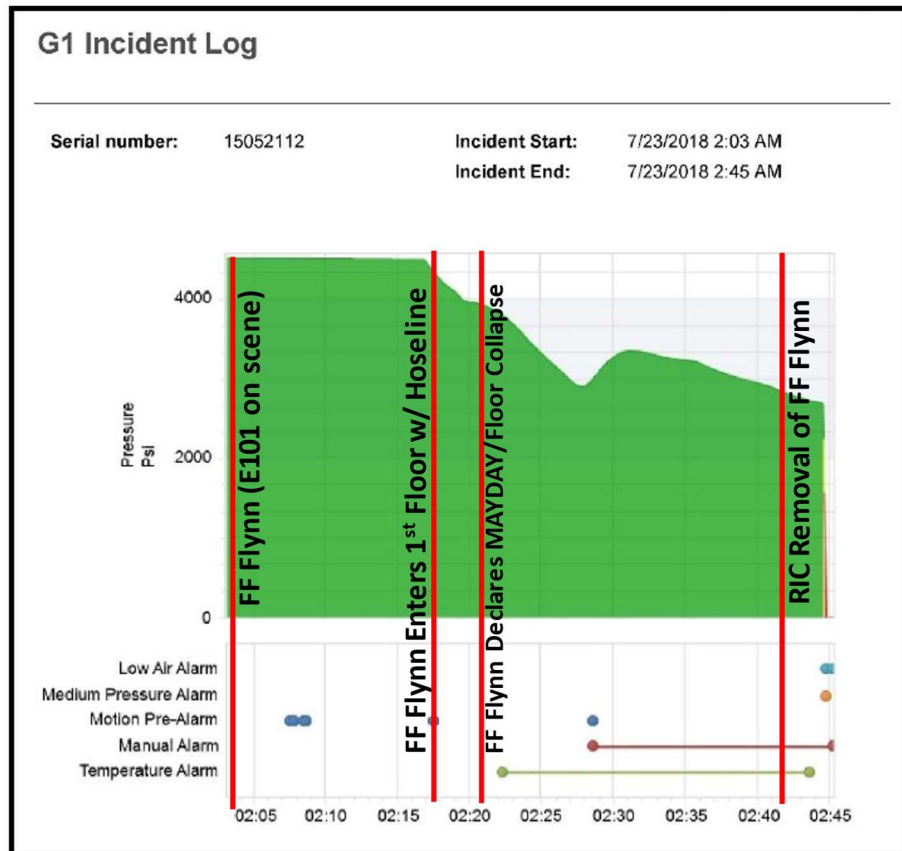
## Analysis of the Line of Duty Death of Firefighter Nathan Flynn Utilizing Computer Fire Modeling (FDS), Fire Testing and Electronic Data Sources



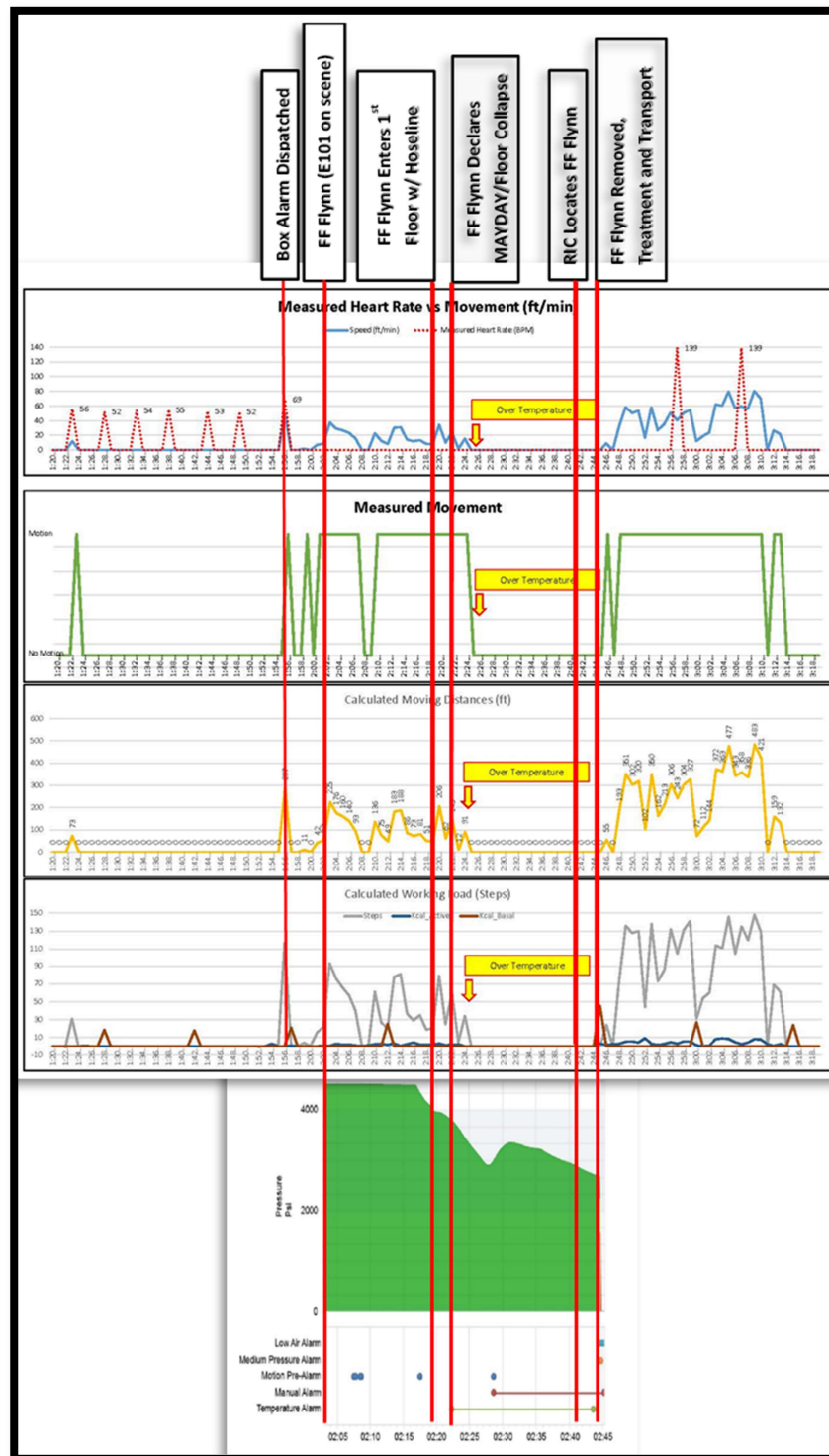
**Self-Contained Breathing Apparatus (SCBA):** SCBA event data logging requirements began in the 2007 edition of the *National Fire Protection Association (NFPA):1981 Standard on Open-Circuit SCBA for Emergency Services*. The data logging capabilities of the SCBA's continued to improve and the standard data logging requirements outlined in NFPA:1981 were updated and enhanced through the 2019 edition of the same standard. Firefighter Flynn's SCBA was outfitted with advanced data logging features that recorded valuable data throughout the fire event, including: air pressure profile, air consumption rate, motion data, presence of SCBA alarms (temperature alarm, low air alarm, motion pre-alarm, manual Personal Alert Safety System (PASS) alarm activation) and event time. ATF and the National Institute for Occupational Safety and Health (NIOSH) Firefighter Fatality Investigation and Prevention Program downloaded and reviewed forensic data from Firefighter Flynn and several other firefighters' SCBA from this incident. This electronic data painted a detailed picture of the events that happened before, during and after the MAYDAY. A visual representation of the data collected from the SCBA was generated by ATF engineers and provided a real-time display of all recorded events for timeline purposes. The SCBA does not directly record specific outside air temperatures during a fire, however a temperature alarm is displayed that indicated when the SCBA detects an environment that may exceed normal operating temperature parameters for the SCBA and firefighter. In this event, Firefighter Flynn's SCBA temperature alarm also corresponded with a consistent increase in air pressure in Firefighter Flynn's air cylinder at approximately 2:27 AM and lasted for about 4 minutes. This increase in air pressure was associated with rapid environmental heating of the SCBA just after Firefighter Flynn fell into the burning crawl space and called his MAYDAY. The air pressure increase began at approximately the same time Firefighter Flynn manually activated the PASS alarm and when the motion pre-alarm self-activated. The SCBA temperature alarm also corresponded to the same time period that the Apple Watch recorded the over temperature event. No specific temperature values can be deduced from the SCBA data, however multiple data sources indicated a rapid heating event immediately after the MAYDAY was declared.



**Figure 17(a). Self-Contained Breathing Apparatus (SCBA) visual event log for Firefighter Flynn including air pressure profile, air consumption rate, motion data, presence of SCBA alarms (temperature alarm, low air alarm, motion pre-alarm, manual Personal Alert Safety System (PASS) alarm activation) and event time. In this event, Firefighter Flynn’s SCBA temperature alarm also corresponded with a consistent increase in air pressure in Firefighter Flynn’s air cylinder at approximately 2:27 AM and lasted for about 4 minutes. This increase in air pressure was associated with rapid environmental heating of the SCBA just after Firefighter Flynn fell into the burning crawl space and called his MAYDAY.**



**Figure 16(b). Self-Contained Breathing Apparatus (SCBA) visual event log for Firefighter Flynn with event timestamps overlayed.**



**Figure 16(c). Overlay of Self-Contained Breathing Apparatus (SCBA) visual event log and Apple Watch visual representation of electronic data for Firefighter Flynn with event timestamps synchronized. The Apple Watch over temperature and SCBA temperature alarm both activate once Firefighter Flynn falls into the crawl space and declares a MAYDAY. Movement data and air consumption rates are also included.**

**Motorola Portable Radio:** Valuable electronic data was transmitted from Firefighter Flynn's Motorola APX8000XE portable radio throughout the incident. Both the radio itself and the Howard County digital radio system logged forensic data, including the channel selected by the portable radio, all audio communications on all radio talk groups, the presence of the automatic "man-down" motion activated emergency alert feature and any manual emergency button alarm activation. It should be noted that Firefighter Flynn did affect a MAYDAY radio call, however the radio was set to broadcast on a separate, unmonitored radio talk group and was not recognized by the communications center or incident commander. Firefighter Flynn's motion activated "man-down" did eventually activate and was relayed to incident command by the communications center. Similar to a SCBA PASS device, the "man-down" radio feature analyzed the physical position of the radio and a motion sensor to automatically transmit a MAYDAY radio call from the portable radio after an elapsed period of time. Firefighter Flynn's portable radio experienced significant heat damage, however it successfully passed a function test post-fire. The radio was located underneath, and protected by, Firefighter Flynn's turnout coat throughout the incident.



**Figure 18. Motorola APX8000XE portable radio possessed by Firefighter Flynn throughout the incident. Forensic data was recovered from the radio and radio system, including the channel selected by the portable radio, all audio communications on all radio talk groups, the presence of the automatic "man-down" motion activated emergency alert feature and any manual emergency button alarm activation. The radio was located underneath, and protected by, Firefighter Flynn's turnout coat throughout the incident.**



## **Analysis of Fire Development in the Crawl Space**

The cause of the fire was classified as “Natural” by the investigative team, resulting from a nearby lightning strike to a large tree. Associated energy from the lightning strike followed a path from the tree, through the soil, to a nearby underground propane storage tank. The propane storage tank supplied the residence through an underground copper supply line that transitioned to metallic Corrugated Stainless Steel Tubing (CSST) that ran through the crawl space beneath the living room. Significant physical damage was observed to both the tree and the soil leading to the propane storage tank.

Fuel gas piping, including CSST, is frequently routed through unprotected (unfinished) sections of residential structural flooring or wall cavities as it supplies gas appliances located throughout the residence. Due to the common placement of gas-fueled appliances in the basement level and throughout the first floor, including the kitchen and living room, CSST is most commonly routed through the combustible structural void space between the basement ceiling and the first floor. In the event of a lightning induced CSST failure, sustained ignition of the escaping fuel gas can occur.<sup>5</sup> The location of the gas lines proximal to combustible structural members can support sustained combustion of these members and fire extension to other fuel items in the basement or first floor. The sustained burning of structural members caused by CSST fires can result in structural compromise and potential collapse from the first floor into the basement.

In this case, the nearby (indirect) lightning strike energized the propane distribution system, and caused the CSST routed below the living room to arc to a nearby grounded object in the crawl space. A metal HVAC duct and a metal dryer vent were located in the immediate vicinity of the CSST arc site, however no corresponding arc site damage to these items was identified by investigators. As the lightning induced electrical energy travels through the thin stainless-steel wall of the CSST, it may contact an adjacent metal object (at a different electrical potential). The result is a high-temperature electrical discharge, or arc, which can create a hole (or multiple holes) in the CSST wall. The energy from this discharge can not only cause a leak of gas, but can also ignite the escaping gas simultaneously. In this case, this event created a small, sustained propane diffusion flame along the ceiling of the crawl space proximal to the wood floor joists and other combustible items stored in that area, including stacked Christmas decorations below. Field fire testing was conducted that estimated this flame to be about 6 inches (15.2 centimeters) in height. At this particular incident, smoke was first noted by occupants approximately 20 minutes after the lightning strike, and Firefighter Flynn’s MAYDAY call occurred 60 minutes following the strike.

In 2011, The Fire Protection Research Foundation funded a research project titled “Final Report for Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage.”<sup>5</sup> The goal of the research was to gain a better understanding of how CSST arc holes form as a result of lightning current and developing potential methods of mitigating such events. The final report referenced three points relevant to this fire incident:

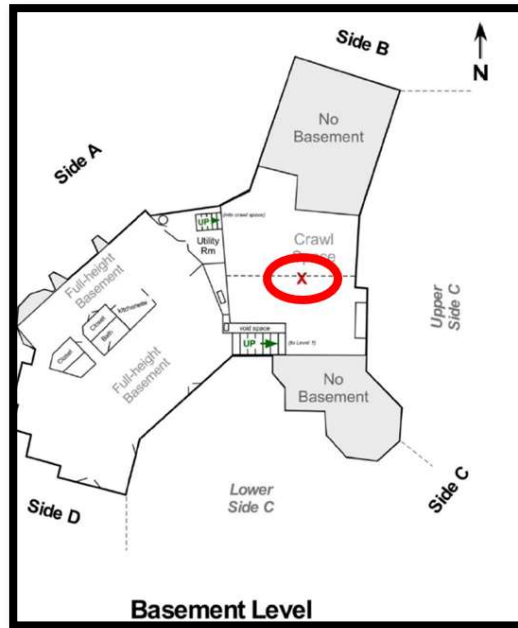
1. “An indirect strike is a strike close to a structure or house, generating a partial lightning current in the metal links of the building (such as gas pipe or electrical grounding) through soil coupling. This partial direct current (which is quite powerful) is able to generate a hole in CSST when an arc is created between CSST and an alternate path to ground (path of lowest impedance).”<sup>5</sup>

2. “For induced and indirect lightning, bonding at the entrance of the installation will help reduce stress, but a global equipotential solution is necessary to achieve a complete solution. Multiple bonding would also help.”<sup>5</sup>
3. “Alternatively, CSST specifically designed to withstand an enhanced lightning surge may be considered, provided their behavior is supported by tests.”<sup>5</sup>

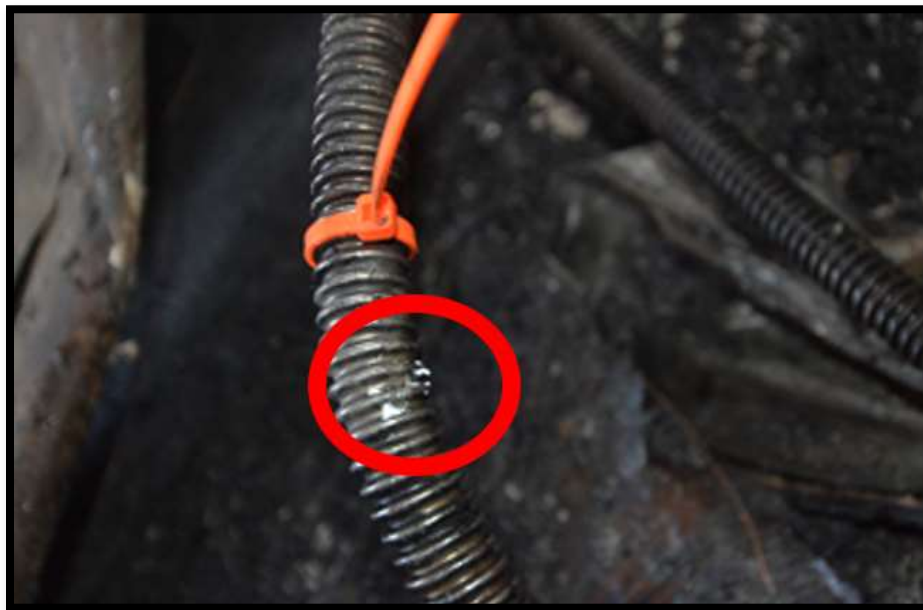
The CSST installed at 7005 Woodscape Drive had no evidence of bonding at the service entrance or manifold. In addition, the CSST was not specifically designed to withstand an enhanced lightning surge.



**Figure 19. Interior photo (post-fire) depicting the living room and crawl space below. The red ellipse indicates the approximate location of the arc hole discovered in the CSST that resulted in sustained ignition of a propane flame approximately 6 inches (15.2 centimeters) in height. The flames eventually spread to wooden structural members and combustible items stored in the crawl space. The yellow ellipse indicates the exterior mud room door that Firefighter Flynn advanced the hoseline through prior to falling into the burning crawl space below.**

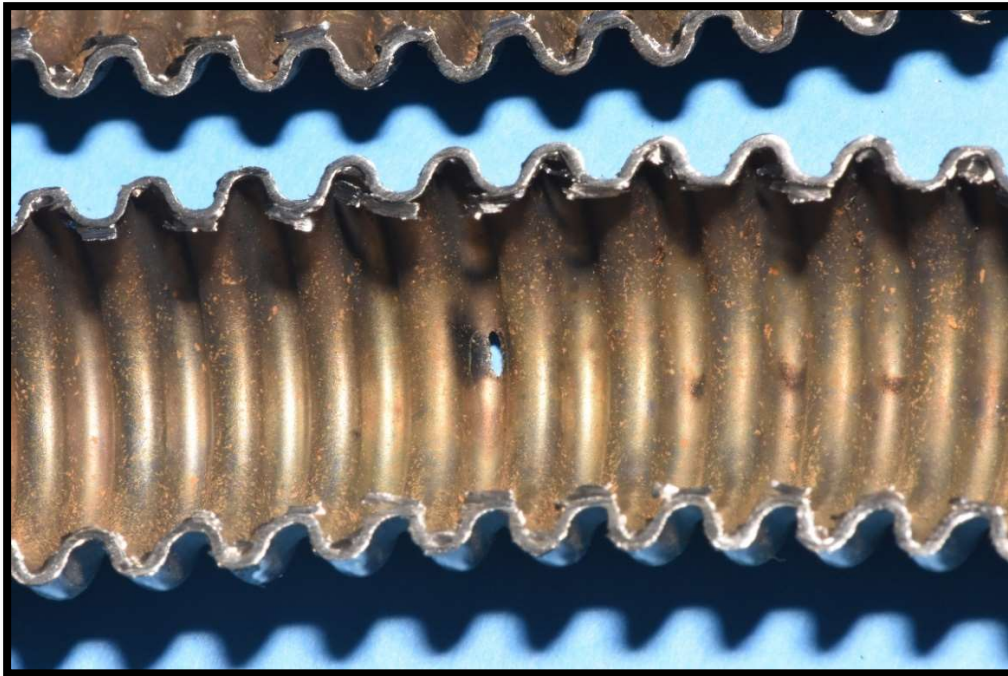


**Figure 20. Diagram of the basement level with red ellipse indicating general location of arc damaged CSST. The living room was located directly above this ellipse. The location of the hole that Firefighter Flynn fell into the basement was located just to the left of the red circle.**

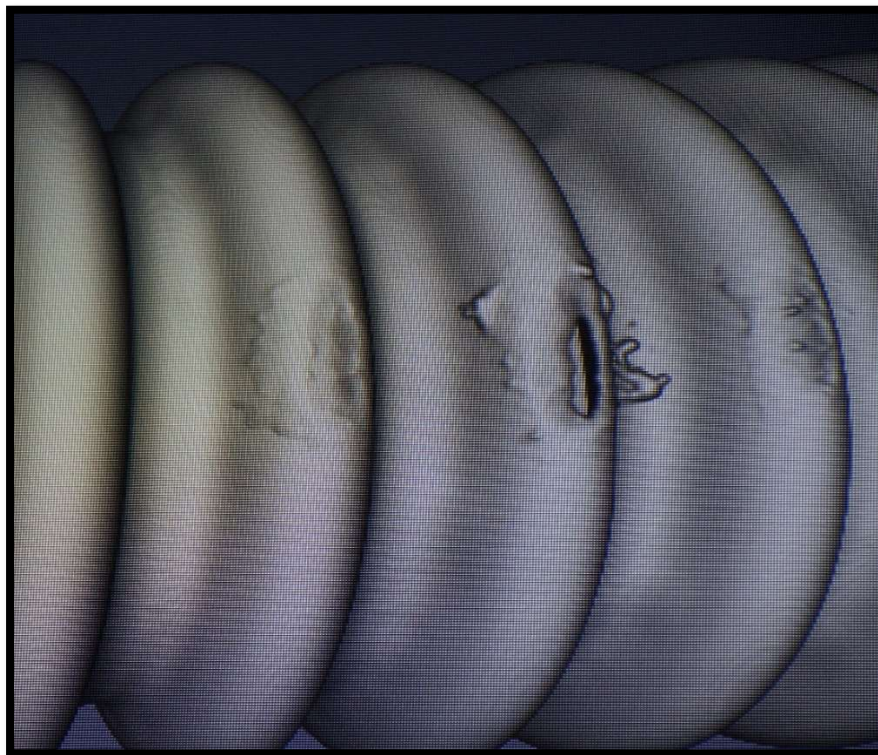


**Figure 21. Scene photo depicting small hole created in the propane CSST supply line. The propane supply tank and associated piping became energized by the nearby lightning strike, causing the CSST to arc to a nearby grounded object. The arcing event melted the thin stainless steel wall of the CSST, which formed a hole and likely ignited the escaping propane. A sustained propane diffusion flame occurred at the location of the hole.**





**Figure 22. Forensic cutaway depicting the inside of the CSST and the arcing damage caused by the lightning strike.**



**Figure 23. A computerized tomography (CT) scan of the CSST arc damage.**



## **Field Fire Testing**

Through careful examination of the scene, investigators were able to identify the location of the hole in the CSST, restore propane gas to the system and conduct field fire tests to determine the resulting flame characteristics. The resulting flame size was documented with the flame directed upward, sideways and downward. An average flame height of approximately 6 inches (15.2 centimeters) was observed when the flame was upright as shown in the image below. The CSST was located immediately underneath the combustibile floor joists and sheathing material for the living room floor above. It should be noted that a hole in the living room floor ultimately forms proximal to the location of the CSST arc hole. Firefighter Nathan Flynn falls through this hole, resulting in the MAYDAY.



**Figure 24. Field fire testing was conducted by ATF at the scene to document flame height using the original propane system. The results of the field fire testing were then used to design subsequent large-scale fire tests at the ATF Fire Research Laboratory.**

## **Large-Scale Fire Testing**

Full-scale fire testing was conducted in the Large Burn Room at the ATF Fire Research Laboratory located in Ammendale, Maryland. For testing purposes, investigators had identified a known heat source (propane diffusion flame), known first fuel ignited (combustible flooring system) and known second fuel ignited (combustible party decorations/supplies). Based on this information, investigators utilized fire testing to gain a better understanding of ignition characteristics, initial fire spread/fire growth profile, mass loss characteristics to combustibile structural components and potential burn-through/hole formation. This information serves as valuable input data for computer fire modeling.

When the large open footprint of the structure is considered as part of the crawl space fire development, it becomes evident that a large supply of fresh air supported fire growth prior to the fire becoming ventilation

limited. In addition, when the residents exited the structure through a mud room door on the Charlie side of the structure, the door was left open and remained open throughout the entire fire. Accordingly, the large-scale fire test structure was left-open and the attached basement was not included as part of this fire test. The basement, 1<sup>st</sup> and 2<sup>nd</sup> levels were included as part of the computer fire model.

The flooring system of the living room consisted of two layers of Oriented Strand Board (OSB), non-combustible Italian tile on top of tile backing, all supported by 2 X 10 floor joists. Large-scale fire testing indicated that the small diffusion flame produced by the propane leak and relatively massive dimensions of the combustible flooring system resulted in a slow growth fire until the flames eventually extended to the other combustible items stored in the crawl space. Residents were first alerted to the presence of a fire approximately 30 minutes after the strike when the intercom system in the residence began to “crackle” and experience electrical problems at approximately 0200 hours. The residents then exited their bedrooms and noticed smoke emitting from an HVAC vent in the area of the living room floor. The residents proceeded to call 911 and leave the structure, leaving the exterior mud room door open behind them.

The following observations were documented from the large-scale fire testing. Despite having significant exposed combustible wood structural material in the crawl space, fire spread beyond the propane leak was slow and remained limited until the flames extended to combustible material stored in the crawl space. This observation is consistent with relatively slow production of smoke initially observed by occupants and firefighters followed by rapidly increasing smoke and heat production within the residence.



**Figure 25. ATF Fire Research Laboratory large-scale testing structure based on several data sources collected at the scene. The structure was built based from original construction documents and included the crawl space (below) and the living room floor support structure above.**



**Figure 26. Top view of the large-scale testing structure. The flooring construction methods were also based on the original construction drawings, including two layers of Oriented Strand Board (OSB), non-combustible Italian tile on top of tile backing, all supported by 2 X 10 floor joists.**



**Figure 27. Large wool area rugs based on the material composition of rugs located in the living room of the actual structure were used for testing. A static load similar to furniture located in the living room was applied using sandbags.**



According to the occupants, the smoke production from the structure intensified quickly, prompting a second call to 911. During ATF fire testing, fire development rapidly intensified only after the fire extended beyond the flooring material to other combustible items stored in the crawl space.

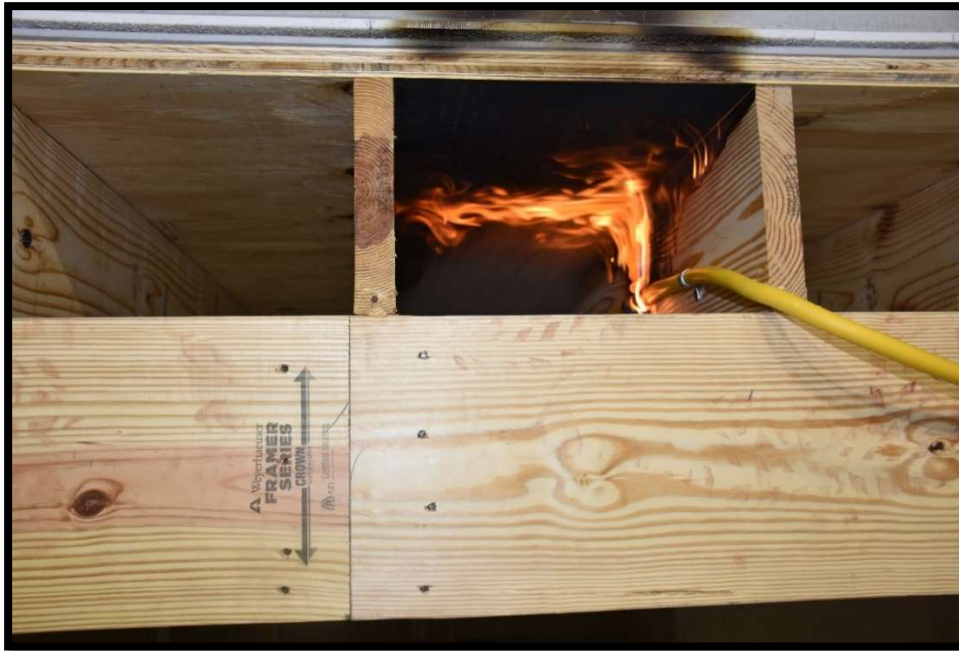


**Figure 28.** A small hole was drilled into the CSST line with similar dimensions to the actual arc hole formed by the lightning strike. Propane was then supplied to the CSST and the pressure was regulated until the flame height was similar to what was measured at the fire scene when the original propane system was field tested.



**Figure 29.** The escaping gas was ignited and flames were allowed to extend to the structural lumber.



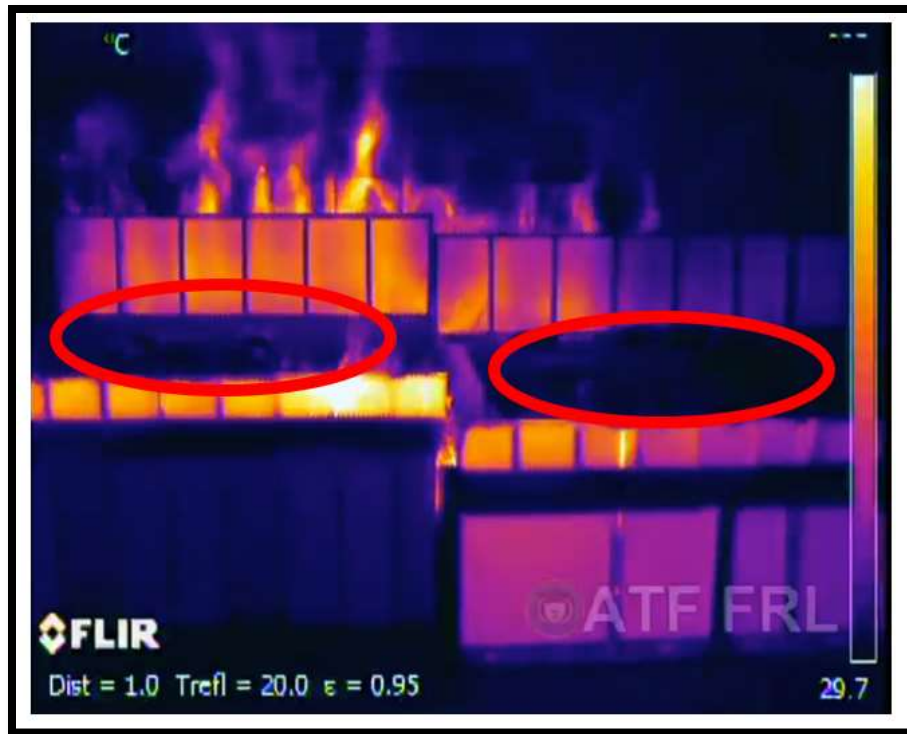


**Figure 30. Despite having significant exposed combustible wood structural material in the crawl space, fire spread beyond the propane leak was slow and remained limited until combustible storage material was ignited below the wooden flooring system.**



**Figure 31. Once combustible materials were ignited below the flooring system, flames rapidly extended throughout the crawl space in just under 10 minutes. This observation is consistent with the relatively slow production of smoke initially observed by occupants and firefighters followed by rapidly increasing smoke and heat production within the residence.**

While the floor joists and OSB sheathing supported flame spread and burned-away, the non-combustible tile and tile backing appeared relatively cool on infrared thermal imaging cameras and remained intact despite having compromised structural support below (Figure 32). The relatively massive construction of the flooring system (thermally thick) masked the heat signatures one might expect from a fully-involved crawl space fire and a structurally-compromised flooring system below.



**Figure 32. Despite having a fully-involved crawl space and compromised structural integrity, the top of the flooring tiles appeared relatively cool on thermal imaging IR cameras (areas circled in red). This same thermal imaging technology was used by firefighters operating on the first floor (above the crawl space).**



**Figure 33. Smoke production through the tile floor with a well-developed fire in the crawl space underneath. The thermally thick (massive) living room floor construction helped mask the well-developed fire underneath firefighting crews operating above.**

Flame extension from the crawl space to the first floor was observed where flooring material was joined together, likely accounting for flame spread from the crawl space to combustible furniture items in the first floor living room as witnessed by firefighters on the exterior. This flame extension was witnessed by firefighters who now believed the seat of the fire was located on the first level, not the basement. This observation resulted in the redeployment of the basement handlines back to the first floor. Firefighter Flynn fell into the crawl space hole a short period after entering the first floor with the hoseline.



**Figure 34. Flame extension from the crawl space to the first floor was observed where flooring material was joined together, likely accounting for flame spread from the crawl space to combustible furniture items on the first floor living room as witnessed by firefighters. This flame extension was witnessed by firefighters who now believed the seat of the fire was located on the first level, not the basement. This flame extension caused firefighters to reposition a hoseline from the basement back to the first floor.**

As is common with modern wood framed flooring systems, limited structural redundancy existed and the failure of a single major structural component resulted in a catastrophic collapse of the entire flooring system during testing. Both in the actual residence and during the ATF FRL fire testing, the columns that supported the flooring system were comprised of three 2x4's nailed together, which was typical throughout the crawl space. Catastrophic collapse of the floor occurred approximately 120 minutes after ignition of the propane flame, 30 minutes after flames extended to combustible storage and 10 minutes after flames began to extend from the crawl space to the first floor during ATF testing. The timeline benchmarks for ignition, flame spread and collapse were consistent between both the ATF FRL testing and the actual fire event timeline.

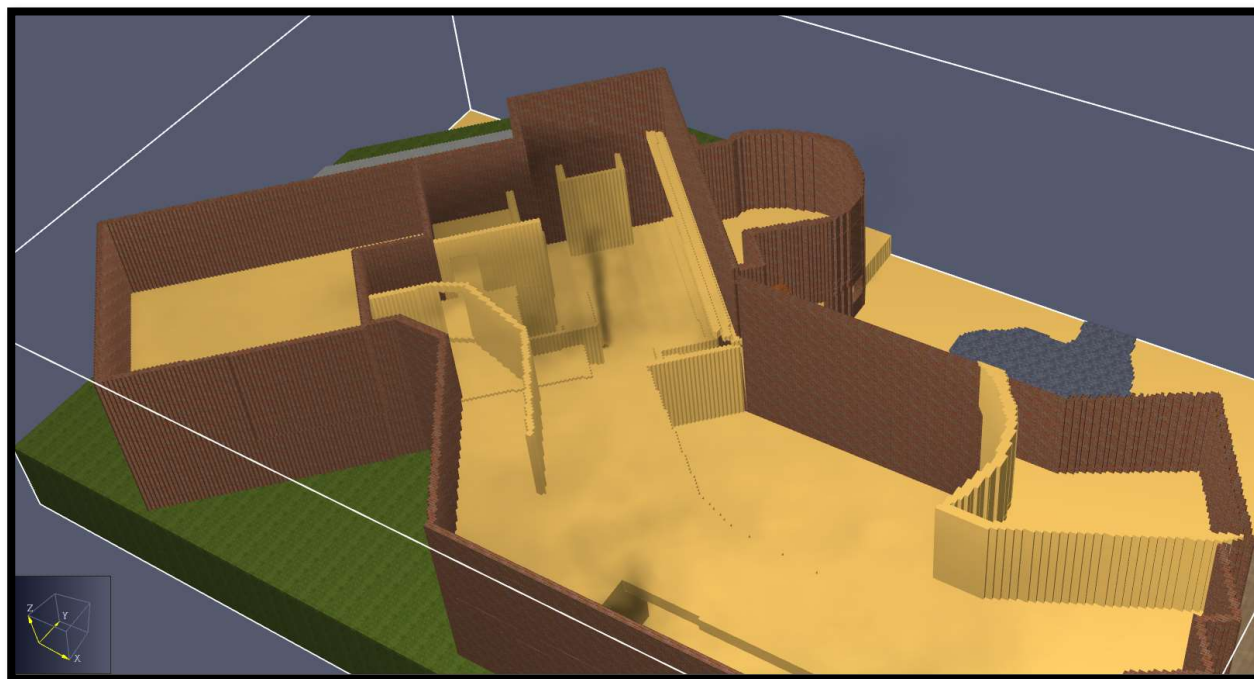
Investigators were able to determine that at least a partial hole existed between the crawl space and first floor prior to Firefighter Flynn falling into the burning crawl space. This hole formation was likely the route of flame spread from the crawl space to the first floor.

### **Fire Incident Progression with Fire Modeling Analysis**

On July 23, 2018 at 01:51:03 a 911 call was received from a resident of 7005 Woodscape Drive reporting a lightning strike and smoke within the house. The caller stated that "we're not sure [what's on fire], we just smelled smoke, and we are out of the house." The 911 operator verified that the resident did not see flames in the structure, only smoke. The caller also indicated that there was a recent lightning strike in the area.

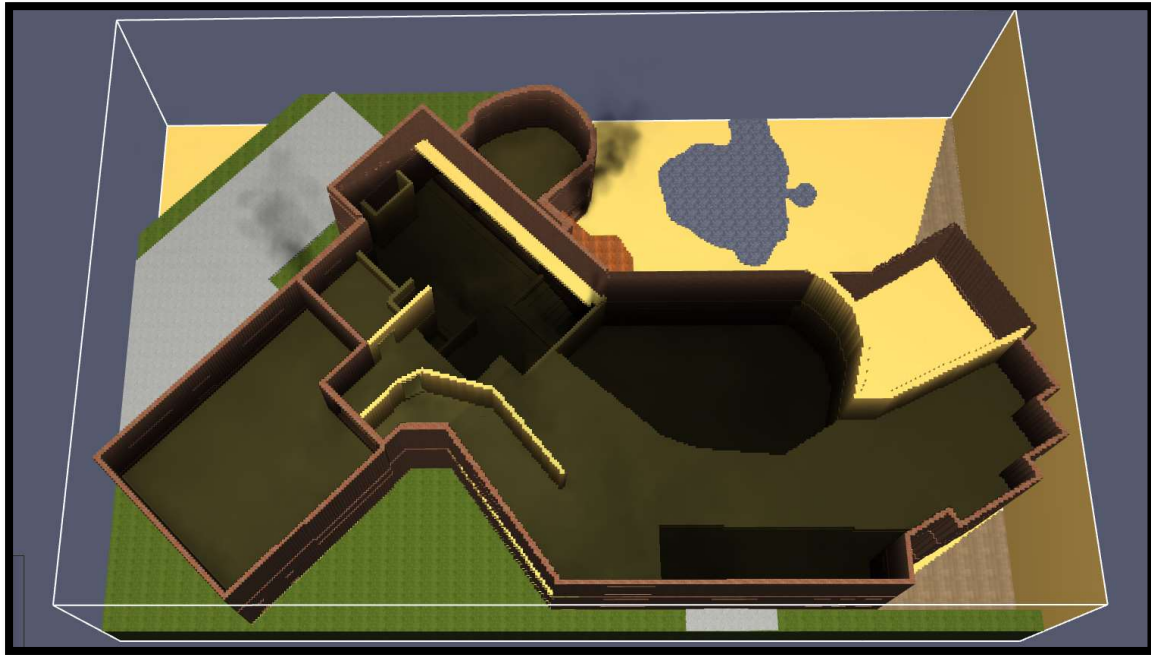


Howard County Communications Center dispatched Local Box 5-62 at 01:52:14 on Radio Talk Group Alpha 1. While units were en route, a second 911 call was received at 01:57:21 to report a fire at 7005 Woodscape Drive from another resident. The second caller indicated that the whole house was filling with smoke, however no flames were visible.

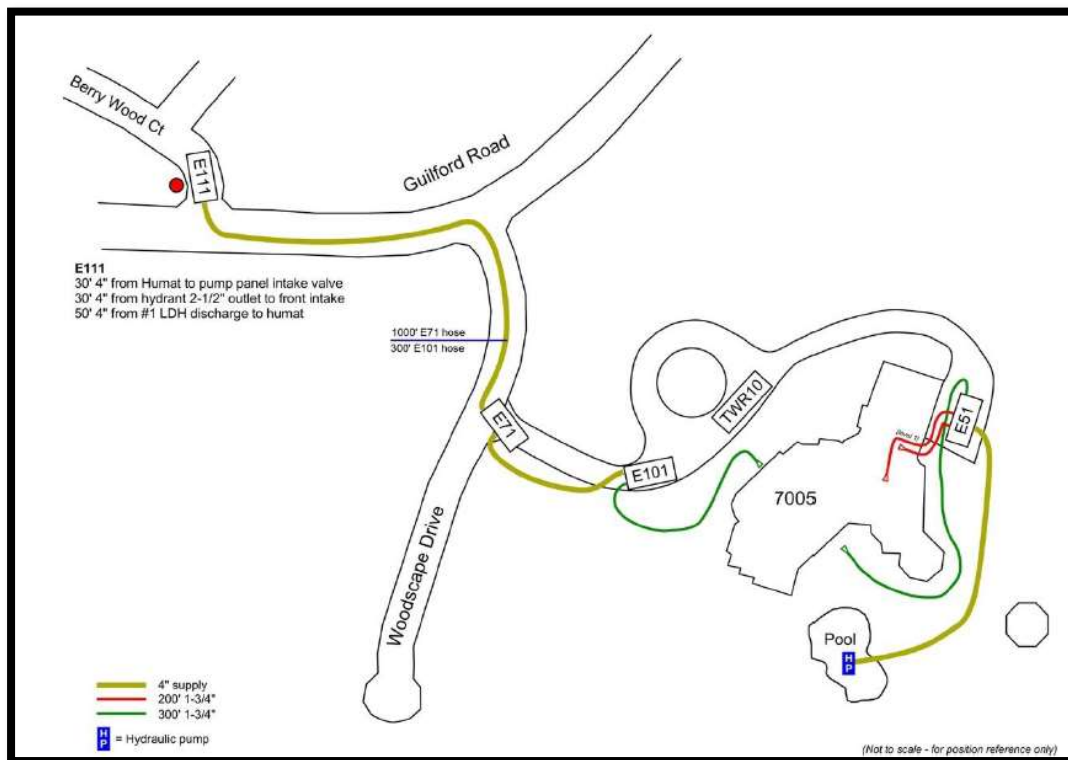


**Figure 35. Pyrosim Results image depicting smoke filling during the incipient stage of the fire. Smoke was witnessed emanating from the floor of the living room (directly above the crawl space) by the homeowners as they exited.**

Upon arrival, Engine 51 noted low-lying smoke across the front lawn and smoke visible from multiple levels of the residence, including the basement level. Engine 51A ('A' denotes the officer position) transmitted the Initial Radio Report (IRR) at 02:00:29 hours, indicating "a single family two-story, smoke showing, go ahead and start a box."

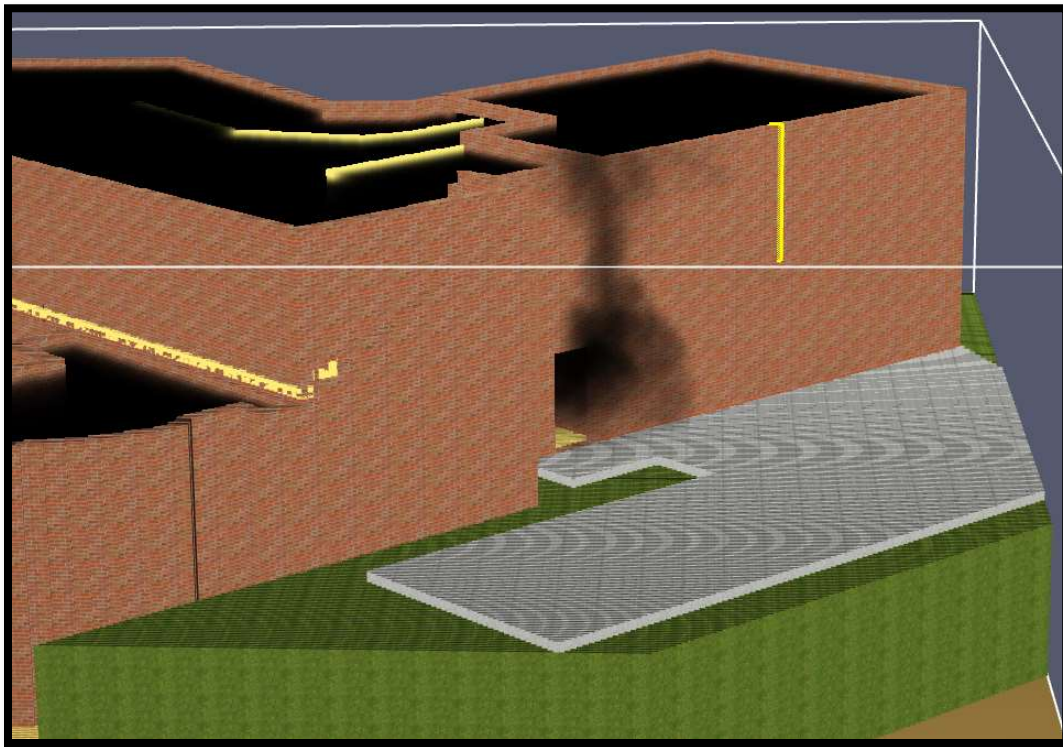


**Figure 36. Pyrosim Results image depicting the residence completely charged with smoke (on all three levels). Smoke can be seen leaking from the basement and through the open upper side C mud room door. This image is representative of conditions encountered by first arriving firefighters.**



**Figure 37. Fire apparatus and hoseline (supply and) placement relative to the structure at 7005 Woodscape Drive.**

While en route to the scene, Battalion Chief 1 directed Engine 51 at 02:01:23 to reposition to the rear of the property to utilize the swimming pool as water supply for the incident. There were no municipal hydrants located on Woodscape Drive and Engine 51 did not lay out supply hose approaching the scene. After repositioning to upper Side C, Engine 51A spoke to the homeowner and determined that the majority of the heavy smoke “was in the basement.”



**Figure 38. Pyrosim Results image depicting smoke emanating from the mud room entrance at the approximate time of first entry by members of Engine 51. Note the bi-directional smoke flow as the basement entrance is shut at this time.**

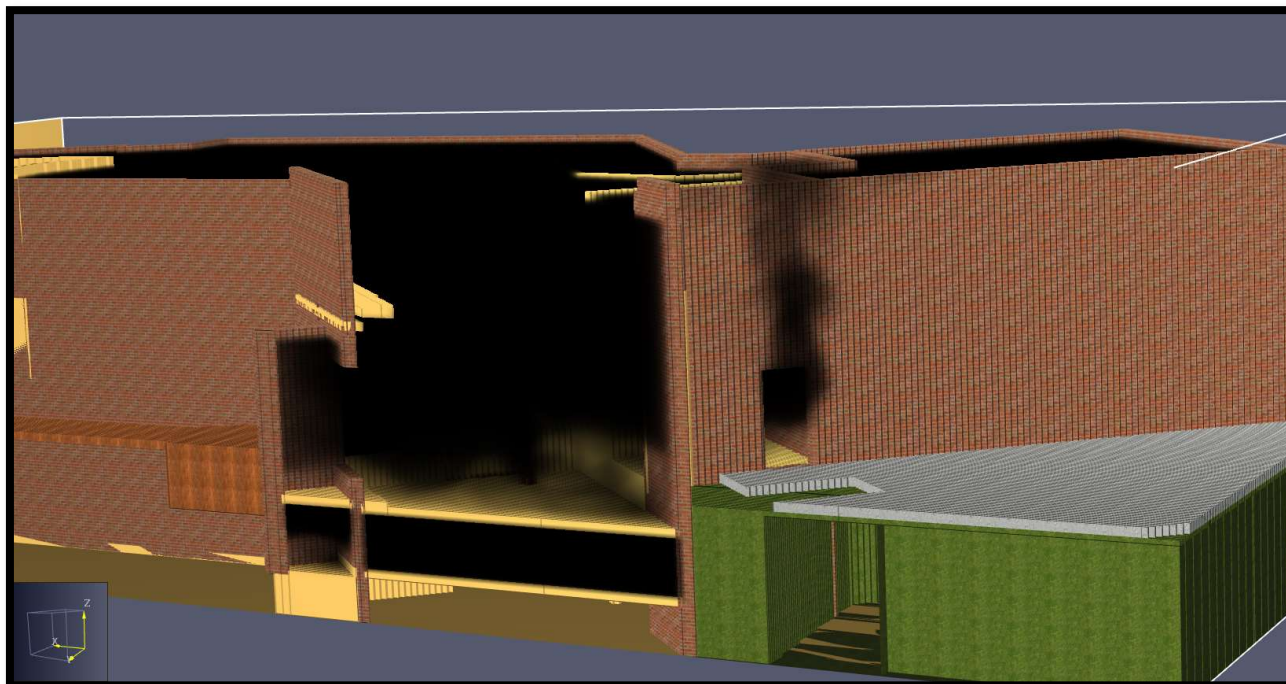


**Figure 39. On scene photograph depicting bi-directional smoke flow from the mud room entrance door prior to the basement door being opened. Note the ventilation limited floor-to-ceiling smoke conditions through the glass door on the first floor.**

The Incident Commander assigned Engine 51 and Tower 10 to the Fire Attack Group, with Engine 51A as the Fire Attack Group Supervisor, at 02:04:31. The Battalion Chief Aide began a 360-degree assessment of the residence, using his phone to take photographs to share with command. The Battalion Chief maintained command from his vehicle positioned on Side A at 02:05:22. Due to the large footprint of the residence, command did not have a direct view of the upper or lower Side C, or a detailed comprehension of the multiple grade changes associated with the complex layout of the residence. Accordingly, command relied on radio reports from the Fire Attack Group for position information and fire conditions.

The crews of Engine 51 and Tower 10 entered the structure on the first floor from the upper level of Side C at approximately 02:07:51 with a charged hoseline, noting moderate smoke conditions from floor to ceiling on the first floor, but no visible flames. Tower 10A and Engine 51B (B denotes the 3<sup>rd</sup> position on the unit) noted indications of a basement fire below them, including high heat levels underneath the area of the mudroom and no indication of fire on the first floor at that time. The crawl space was located directly underneath the mudroom and living room. The initial entry on upper Side C (the mud room) and conditions observed on the first floor of the structure were not reported to Incident Command.





**Figure 40. Pyrosim Results image depicting smoke conditions in the basement and crawl space. Engine 51 crew members identified that the fire was likely in the basement and withdrew from the first floor to reposition to the basement entrance.**

As this was occurring, Engine 101B (Firefighter Flynn) pulled a 300 foot 1¾ inch attack hose from Engine 51 and initially intended to backup Engine 51 on the first floor, however they later redeployed the hoseline to the Side C basement entrance without ever making entry to the first floor after Engine 51 and Tower 10 withdrew from the structure. After withdrawing from the first floor kitchen/mud room entrance area, Engine 101 then deployed a 300-foot hoseline and Engine 51 moved their 200-foot hoseline to the side C basement entrance. However, Engine 51's 200-foot hoseline did not reach the basement entrance of the structure. Firefighter Flynn then proceeded to enter the basement on the lower level of Side C with the 300-foot charged hoseline, however the fire in the crawl space could not be immediately located.



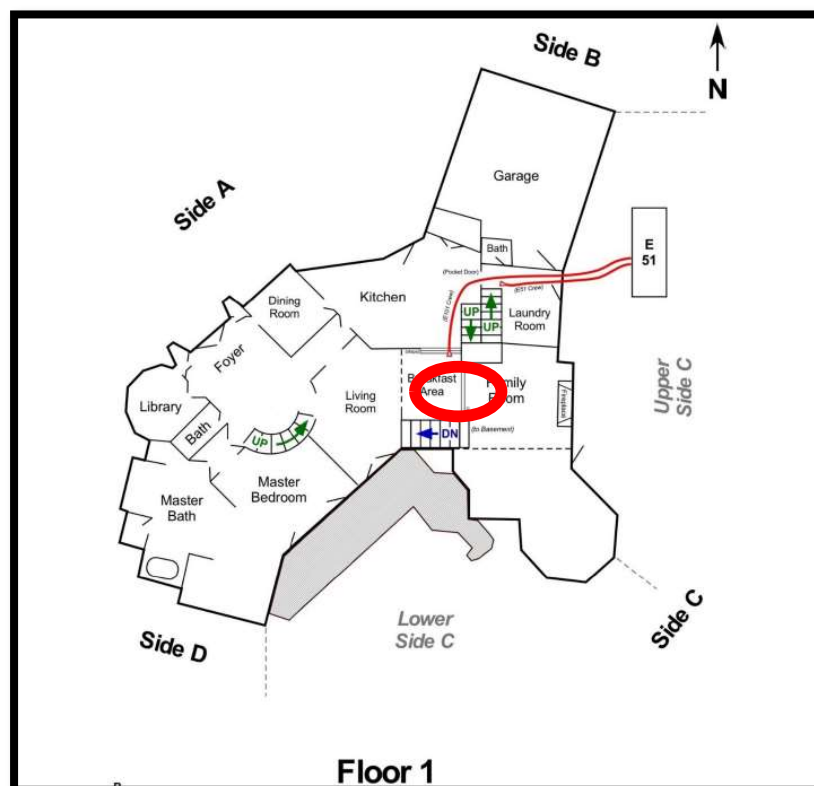
**Figure 41. Pyrosim Results image showing the smoke conditions encountered in the basement when crews first opened the basement door. Opening the basement door created a unidirectional flow path with the basement door acting as the inlet and the mud room door acting at the outlet. The influx of air caused the fire in the crawl space to intensify and spread to items on the first floor. Exterior crews now noticed flames on the first floor and believed the seat of the fire to be on the first floor.**

As Firefighter Flynn was advancing the hoseline into the basement, Engine 101A ('A' denotes the officer position) advised the Incident Commander by radio that they now witnessed flames in the living room from the exterior where fire was not previously evident. Firefighters believed the seat of the fire was on the first floor as the smoke layer in the basement was elevated and not indicative of a typical basement level fire. In addition, they now saw flames on the first floor. Engine 101A radioed "heavy fire on floor number one Side Charlie. We need to redeploy our line back up to the initial entrance." Firefighter Flynn responded by withdrawing from the lower level Side C basement entrance with the hoseline, closing the basement entrance door and abandoning the 300-foot hoseline outside of the basement entrance before proceeding with other crews back to the upper level Side C first floor entrance. The upper level Side C (first floor) mud room entrance door remained fully open from the time the homeowners initially called 911 throughout the entire fire incident.

Firefighter Flynn then proceeded back to the upper level Side C mud room entrance door and deployed a second 200-foot hoseline from Engine 51. Firefighter Flynn followed by Engine 101A made entry into the first-floor mud room on the upper level Side C. The mud room opened directly into the kitchen area and hallway to the living room where flames were previously witnessed by Engine 101A through an exterior window. Engine 101A was an unknown distance behind Firefighter Flynn, feeding hoseline as Firefighter Flynn advanced towards the previously seen flames. Engine 51's crew redeployed their charged hoseline from lower level side C to upper level Side C and made entry on the first floor behind Engine 101A at approximately 02:17:43.



**Figure 42.** Pyrosim Results image depicting conditions when crews re-entered through the laundry room (mud room) door to attack flames seen on the first floor. Flame extension from the crawl space to the floor occurred via a hole that formed near the area of the propane leak in the CSST.



**Figure 43.** First floor diagram depicting the location of two hoselines pulled from Engine 51 through the mud room door. Firefighter Flynn falls from the first floor into the burning crawl space where the hoseline enters the

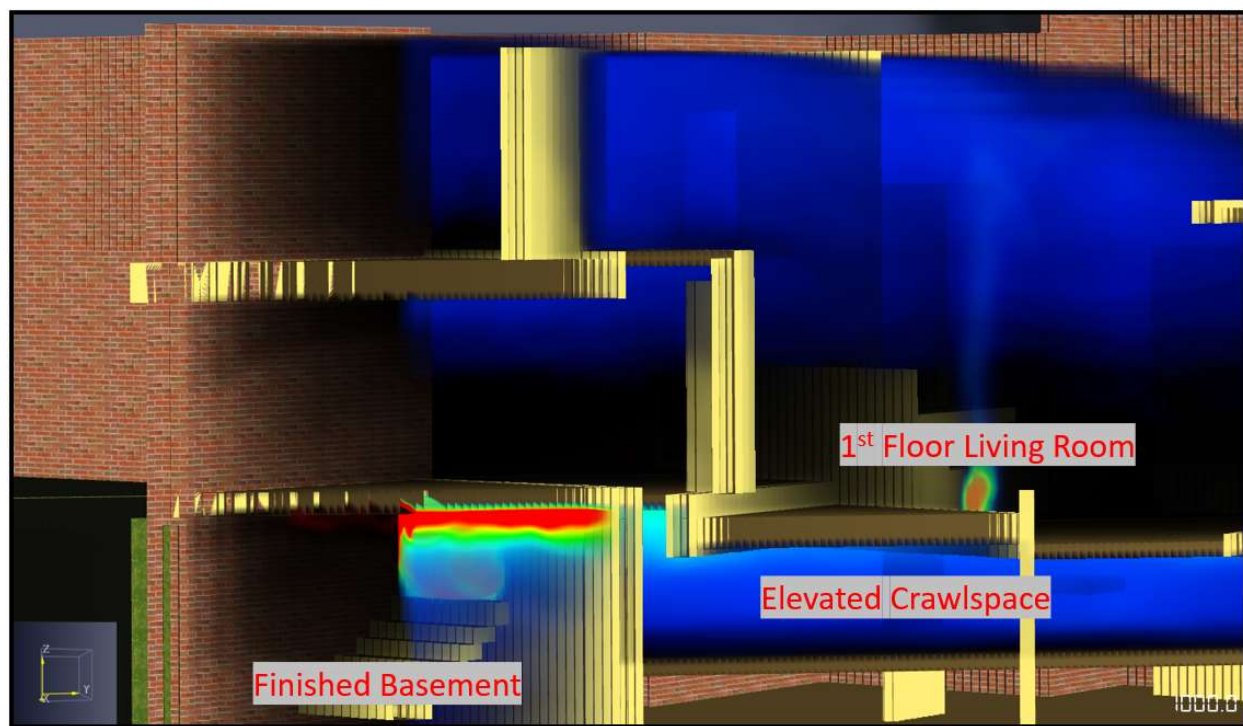


**Breakfast Area. Additional hoselines were also pulled from Engine 51 to the rear basement door (not pictured). Red circle indicates approximate location of the hole.**

At 02:18:29 hours Incident Command assigned Truck 7 as the Rapid Intervention Team (RIT) and Engine 71 was positioned on Side A.

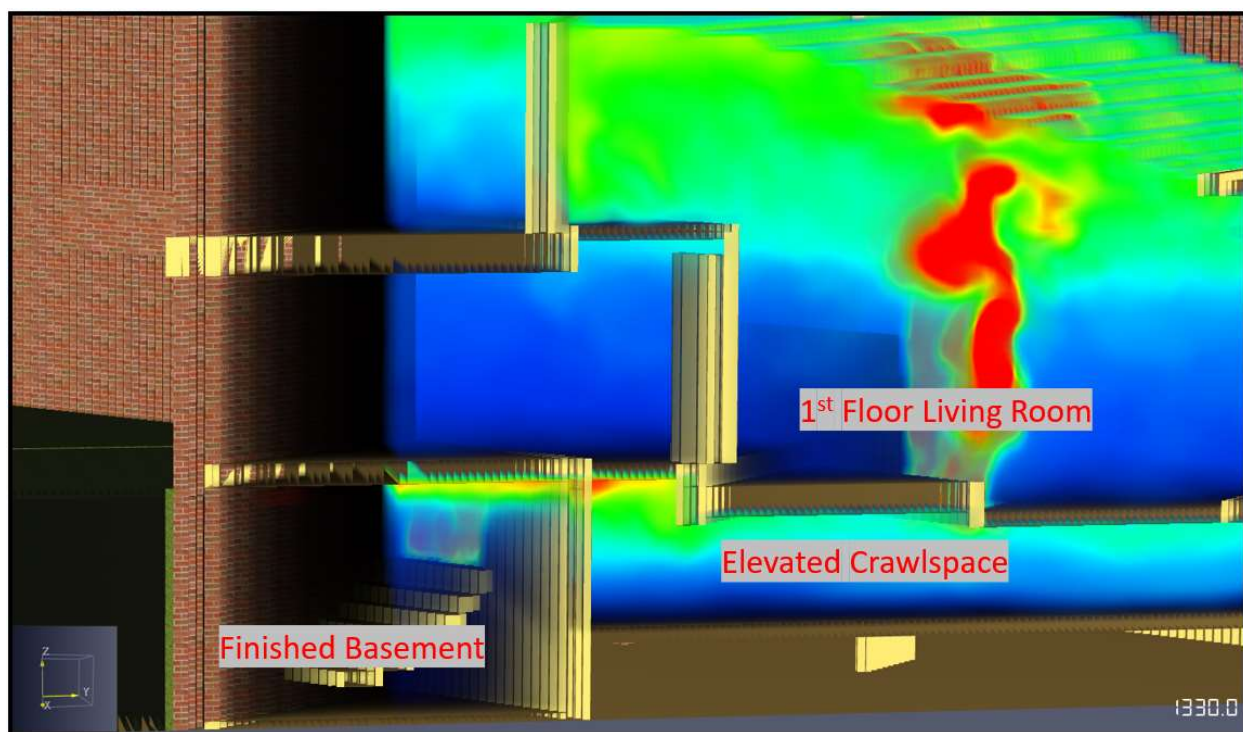
After advancing the hoseline through the first floor kitchen and towards the flames in the living room for a period of approximately 2 minutes, Firefighter Flynn fell through a hole in the first floor living room, down into a crawl space at approximately 02:19:45 along with the hoseline. At 02:20:11, Engine 101A transmitted, "MAYDAY, MAYDAY, MAYDAY, Flynn's in the basement to the left" on the operations channel, Bravo 1. Engine 101A's MAYDAY transmission was immediately acknowledged by the Incident Commander, however the Incident Commander was unclear who was experiencing the MAYDAY due to the transmission's clarity.

The Communications Center advised Command that the transmission was from 101A. At 02:21:05 Engine 101A transmitted on Bravo 1 "he's in the basement, hoseline trying to pull him up, go through the basement." Simultaneously, Firefighter Flynn mistakenly transmitted a MAYDAY call for assistance on an unmonitored Bravo 2 radio talk group. Accordingly, Firefighter Flynn transmission was not heard by either the Incident Commander or the Communications Center.



**Figure 44. Pyrosim Results image (Sectional view) depicting smoke filling and relative temperature just prior to the MAYDAY. The stairs leading up to the crawl space entrance can be seen on the left side of the image.**





**Figure 45. Pyrosim Results image (sectional view) depicting smoke filling and relative temperature during the MAYDAY and RIT rescue operation. Flames intensified as the size of the hole increased and additional air was introduced through the basement door. The stairs leading up to the crawl space entrance can be seen on the left side of the image.**

The hole acted like a chimney and a unidirectional flow of hot exhaust gases flowed through the hole and out of the mudroom door. The free-burning crawl space and the fire gases venting up through the hole created untenable conditions for firefighters on the first floor to attempt a rescue from above. The RIT crew and rescue operations were directed from the basement level at-grade entrance on lower side C.

Engine 71A and Truck 7A were the first members of the RIT to enter the basement. They reported "cold smoke" conditions creating poor visibility for the members entering. Truck 7B first came across a set of steps that led to the first floor near the area where Firefighter Flynn fell through the hole in the floor. Truck 7 and Paramedic 56 located a second set of partial steps located on the front wall of the basement through a butler's kitchen area. Crews could hear and see flames coming from the top of the partial stairs that led to the intermediate crawl space.

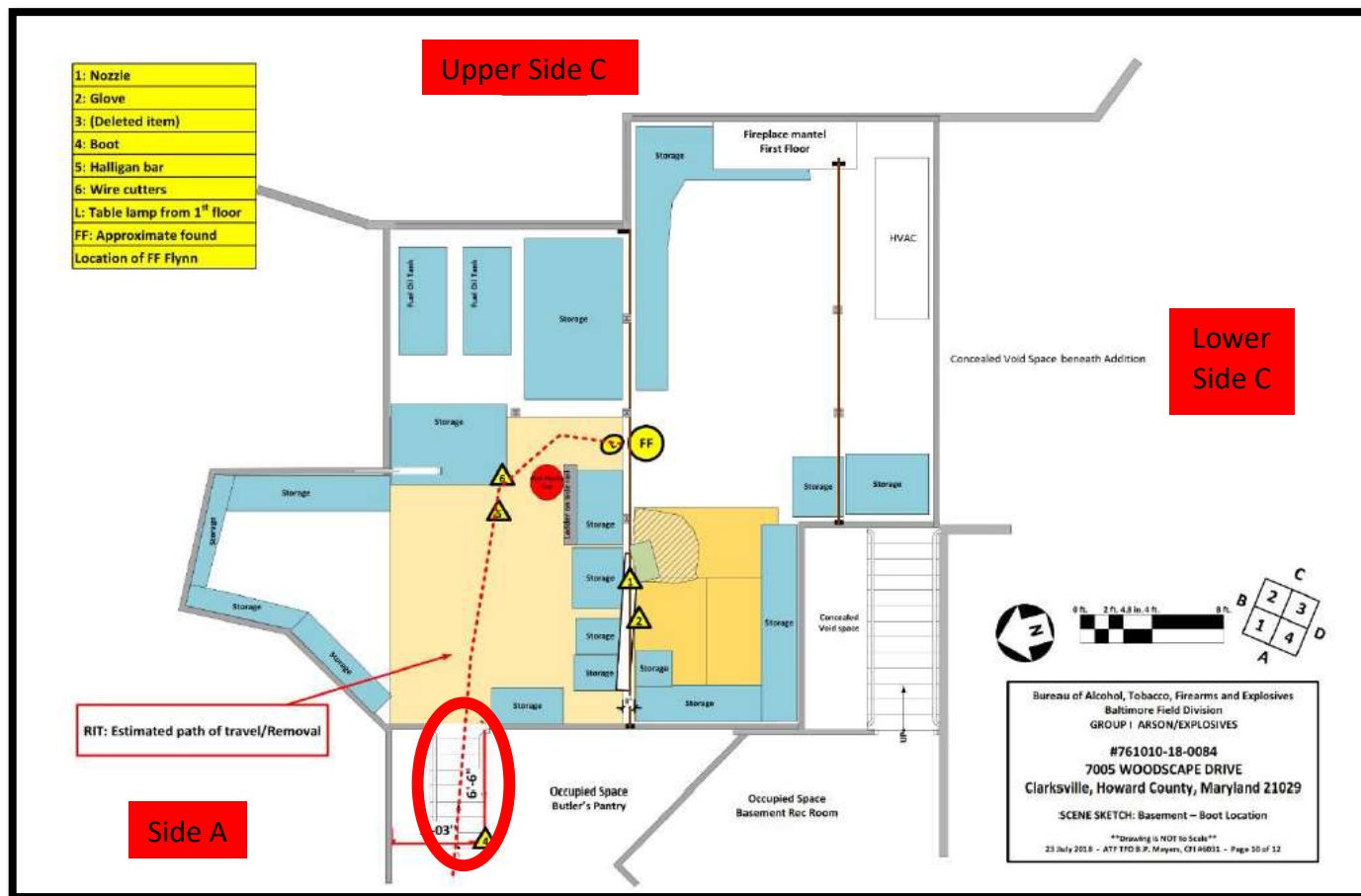
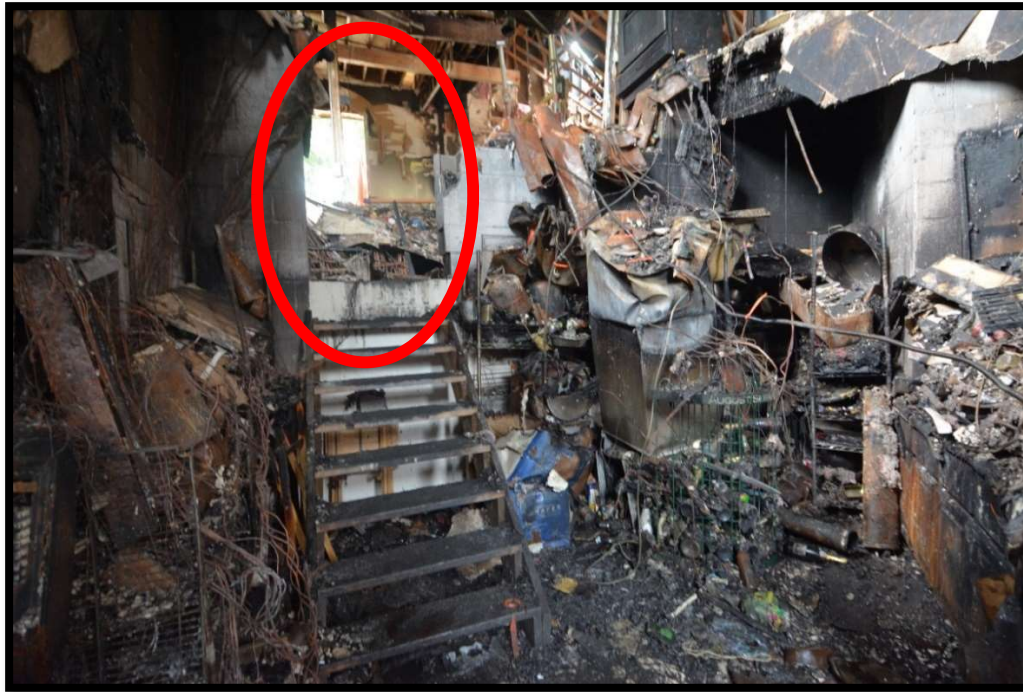
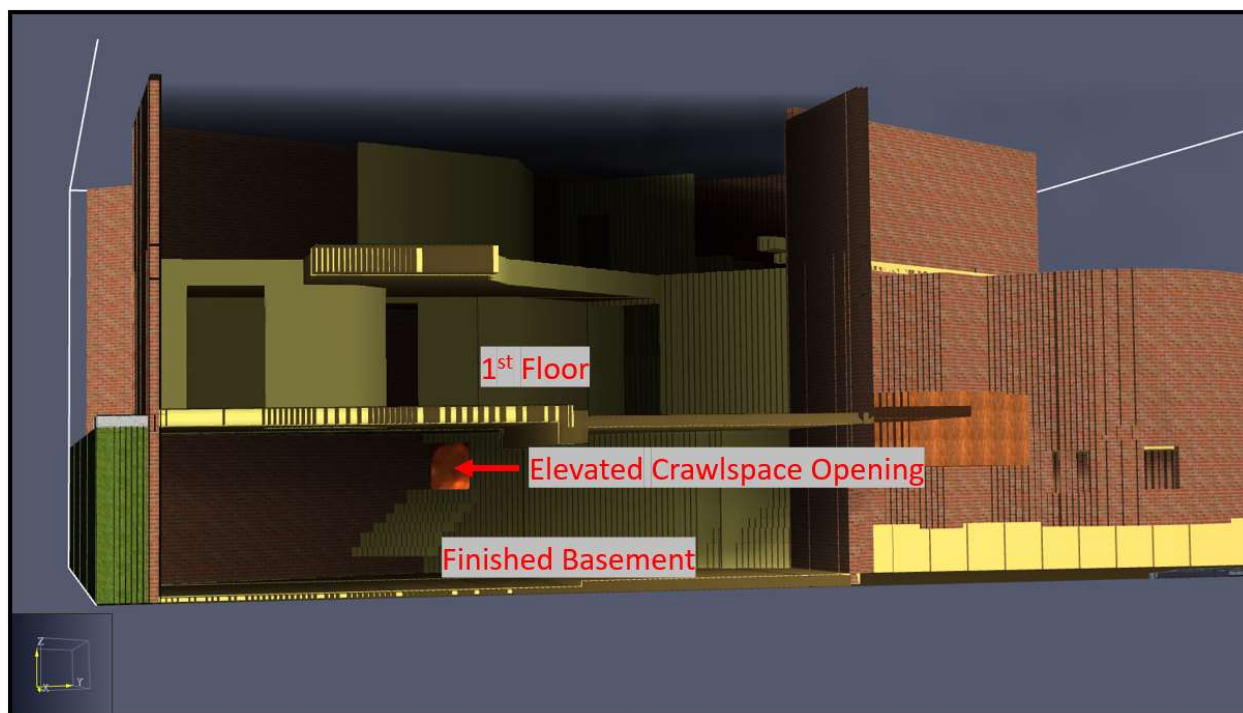


Figure 46. Crawl space diagram depicting the ½ flight of stairs leading from the basement to the small crawl space entrance. No door was present at the entrance to the crawl space. The red dotted line indicates the path taken by RIT crew members to locate and extricate Firefighter Flynn. Firefighter Flynn's location is depicted by a yellow circle.



**Figure 47. Post-fire photograph indicating the ½ flight of stairs leading from the basement to the entrance to the crawl space. Note that the crawl space floor is elevated approximately 5 feet (1.5 meters) above the basement floor. RIT crews immediately encountered flames upon entering the crawl space. Firefighter Flynn was removed by the RIT through this opening.**

Members of the RIT stated that as they got to the top of the stairs to the crawl space, visibility was low, the heat had increased, and they were able to hear Firefighter Flynn's personal alert safety system ("PASS") alarm. RIT members entered the crawl space and advanced a hoseline, simultaneously suppressing flames and cutting crew members free as they became entangled in metal conductors spanning the crawl space.



**Figure 48. Pyrosim Results image (sectional view) depicting fire conditions at the crawl space entrance during the MAYDAY/RIT operation. Crews encountered “cold smoke” in the basement and flames throughout the crawl space.**

The RIT located Firefighter Flynn lying face down in a portion of the crawl space used to store Christmas decorations, just where the crawl space transitioned from the area below the kitchen to the area directly below the living room. The gauge on Firefighter Flynn’s self-contained breathing apparatus ("SCBA") showed that he still had cylinder air pressure above the red zone. Accordingly the RIT prioritized removing Firefighter Flynn over attempting to buddy-breathe or trans-fill SCBA air cylinders. Crews successfully removed Firefighter Flynn through the smoldering debris in the crawl space, down the narrow stairs and out through the lower Side C basement entrance door. Firefighter Flynn was transferred to EMS personnel outside the basement level entrance for patient care and packaging.

Treatment of Firefighter Flynn continued at Howard County General Hospital until the physician determined that all efforts of resuscitation had been exhausted. The State Medical Examiner determined the cause of death to be an accident due to “prolonged exposure to high temperature and thermal injuries."



## ANALYSIS AND CONCLUSIONS

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### **7005 Woodscape Drive Computer Fire Modeling Analysis and Conclusions:**

After reviewing the totality of the forensic data and fire testing data collected during this investigation, several conclusions were generated regarding fire dynamics and the overall fire timeline. It should be noted that the scope of ATF's analysis is limited to sharing specific forensic data related to the fire event as well as a review of the fire dynamics (smoke filling, fire spread, flow path analysis, etc.) that occurred. Howard County Fire and Rescue and the National Institute for Occupational Safety and Health (NIOSH) have each generated separate reports that address firefighting tactical considerations specific to the Woodscape Drive LODD incident.

#### **1. Extremely large volume of the residence allowed for a well-developed fire, despite light smoke showing on exterior:**

According to the U.S. Census Bureau, the average square footage of single family residences in the United States increased by approximately 70% between 1960-2004. "The 2009 American Housing Survey shows that homes being built today are bigger than those built in earlier decades. In addition, homes built today have almost more of everything – different types of rooms such as more bedrooms and bathrooms, more amenities such as washers and dryers, garbage disposals and fireplaces."<sup>6</sup>

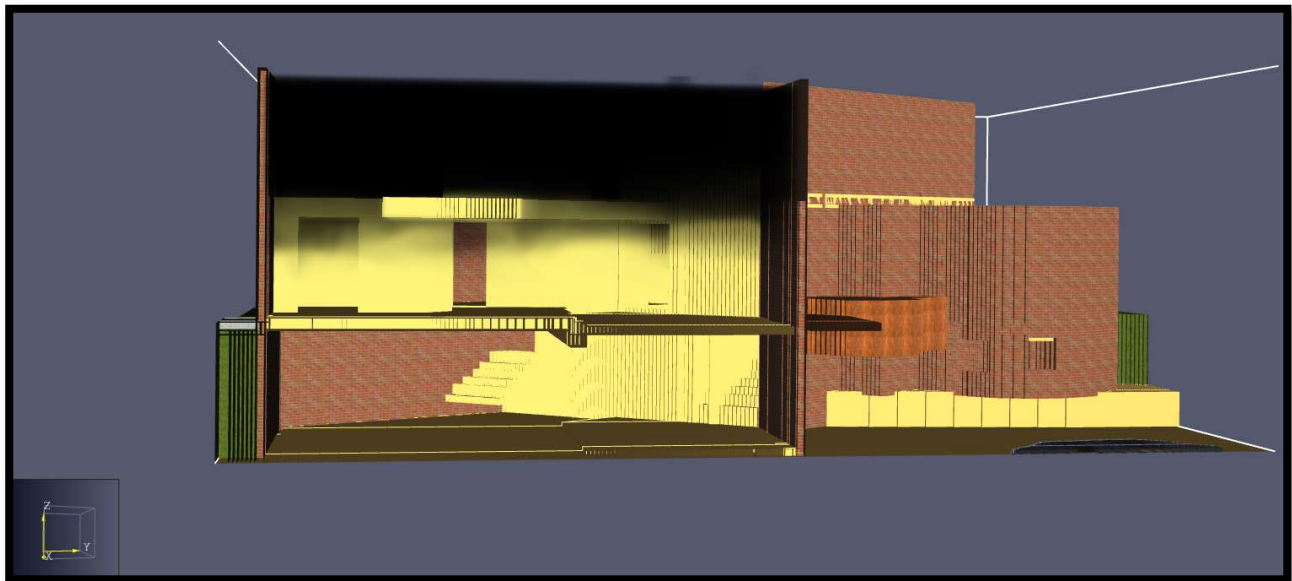
The residence at 7005 Woodscape Drive consisted of approximately 8,400 square feet of open living space that spanned three continuous (non-compartmented) levels. When firefighters arrived, the entire structure (all three levels) were filled with smoke and light smoke was also evident from the exterior. No flames were visible until much later into the incident. Dense smoke throughout a typical residence (2,000-3,000 sq. ft.) without visible flames is a routine encounter for firefighters and is usually indicative of a manageable, likely ventilation limited fire. Fire dynamics in extremely large residences is markedly different; especially with regards to fire growth prior to the fire consuming available oxygen and becoming ventilation limited.

At this fire, the volume of the house was almost three times larger than what many firefighters routinely encounter. In this case, when significant smoke was encountered throughout all 8,400 sq. ft. of the residence, a well-developed fire existed throughout the entire crawl space, even though the typical visual and physical cues firefighters relied on indicated otherwise. Once a residence fills with dense smoke and the smoke layer drops below the level of the flames, the fire will likely become ventilation limited and the heat release rate (fire size) will be limited. Under similar circumstances, a fire that has three times more air (enclosure volume) available will be allowed to release three times more energy prior to becoming ventilation limited. This increased fire growth, fire duration and total heat released creates additional fire suppression challenges and also increases the potential for structural collapse. A fire that is allowed to burn freely for a longer period prior to becoming ventilation limited, will also consume more fuel. This extended burn period can result in greater consumption of combustible structural members, which further increases the risk of structural collapse.

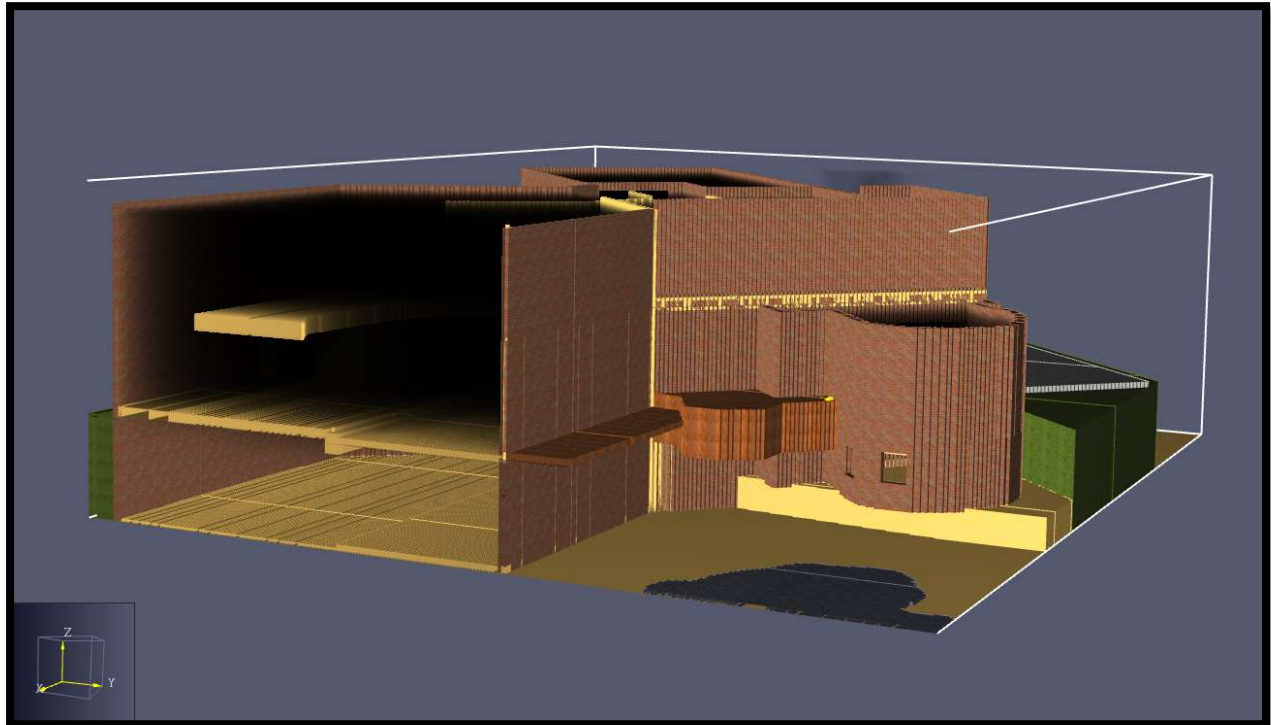
Computer fire modeling can assist with comparing smoke filling behavior with prescribed fires on different levels of the residence to gain a better understanding of the relative time to when the fire will become ventilation limited and the heat release rate of the fire would be expected to decrease. A 3 megawatt design fire ( $t^2$  with 360 second ramp up time) was placed individually on all three levels of the residence as part of

alternative computer modeling runs to individually compare smoke filling and the relative time to reach ventilation limited conditions. Ventilation limited conditions were estimated when the smoke layer accumulated downwards below the level of the flames and should be considered for relative comparison purposes.

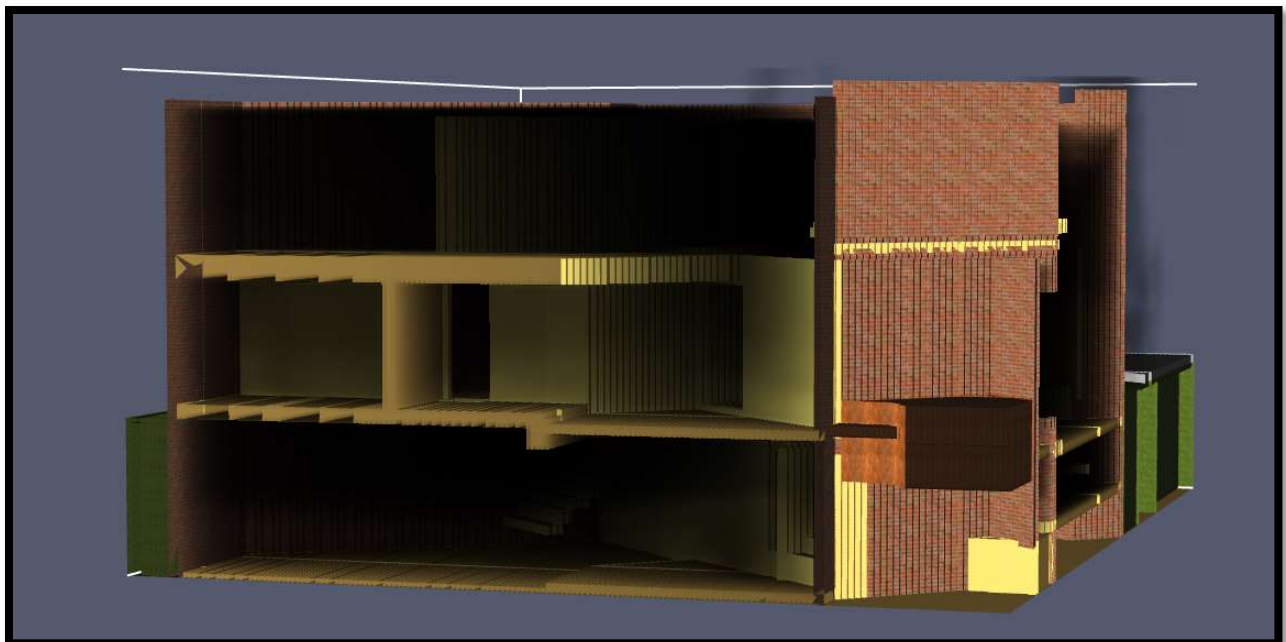
Fire Level	Approximate Time to Ventilation Limited Conditions at Fire Location
2 <sup>nd</sup> Floor	280 seconds of fire growth
1 <sup>st</sup> Floor	385 seconds of fire growth
Basement	820 seconds of fire growth



**Figure 52. Pyrosim Results image indicating smoke filling and ventilation limited conditions reached after 280 seconds of fire growth. The fire was placed on the 2<sup>nd</sup> (top) floor, allowing the fire to grow for 280 seconds until the smoke layer dropped below the level of the flames, thus limiting fire growth.**



**Figure 53. Pyrosim Results image indicating smoke filling and ventilation limited conditions reached after 385 seconds of fire growth. The fire was placed on the 1<sup>st</sup> (middle) floor, allowing the fire to grow for 385 seconds until the smoke layer dropped below the level of the flames, thus limiting fire growth.**



**Figure 54. Pyrosim Results image indicating smoke filling and ventilation limited conditions reached after 820 seconds of fire growth. The fire was placed in the basement, allowing the fire to grow for 820 seconds until the smoke layer dropped below the level of the flames, thus limiting fire growth.**

Firefighters can use the height of the smoke layer to assist them in locating the level of the fire. It is often safest to attack the fire from the same level of the flames, or the level below, where possible. In addition, personnel may also consider the level of the fire/smoke filling of the structure when determining how much oxygen may have been available to a fire prior to arrival. Fires located on the top floor of a residence often become ventilation limited much sooner (and are easier to locate/suppress) as compared to the same fire located in the basement, as the smoke layer takes longer to descend to the level of the flames. Again, firefighters should consider ensuring that the basement is completely free of smoke and fire, including at the basement ceiling level where CSST may be routed, as part of fire scene size-up operations.

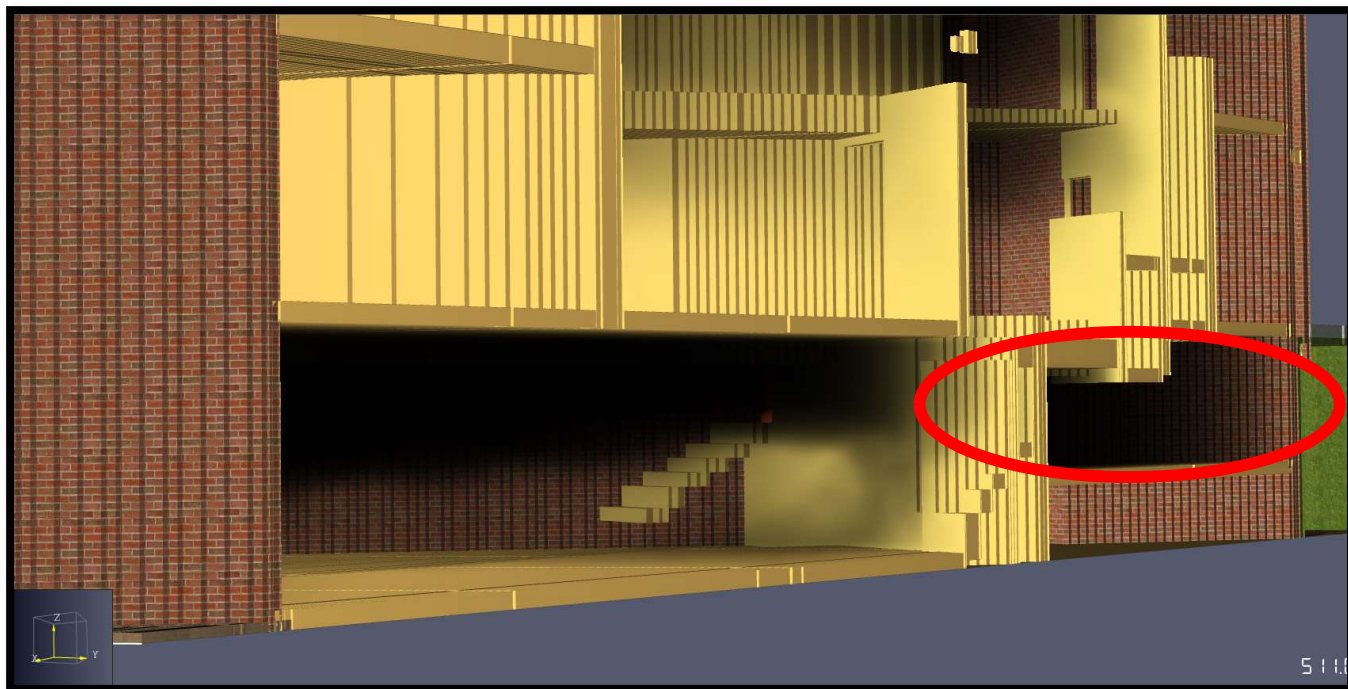
## **2. Elevated fire located in the basement crawl space created atypical smoke filling conditions in basement:**

The crawl space was located at an intermediate height, approximately 1.5 meters (5 feet) above basement floor and below the level of the first floor. When crews initially entered the first floor, they identified heat and smoke signatures consistent with a basement fire below them. Upon repositioning to the basement level, the same crews identified smoke filling consistent with a fire above the basement level due to relatively elevated “cold smoke” and minimal heat in the basement. The crew then withdrew from the basement once flames were seen in the first floor living room from the exterior. The fire conditions observed were inconsistent with a fire in the basement and also inconsistent with a fire on the first level. In reality, the crews correctly identified an elevated fire (in the elevated crawl space) that was in fact below the first floor and also above the basement level.



**Figure 49. Pyrosim Results image (sectional view) depicting the height of the crawl space relative to the first floor mud room entrance. The crawl space is circled in red.**





**Figure 50. Pyrosim Results image (sectional view) depicting the height of the crawl space relative to the basement. The crawl space is circled in red.**

Fires elevated in height within an enclosure (crawl space relative to basement floor height, fires located at ceiling level, or even stovetop fires) result in unique smoke filling characteristics in the larger enclosure. Frequently ventilation limited conditions occur prior to the smoke layer reaching the level of the floor. Once the smoke layer reaches the level of the flames, the fire size typically decreases (becomes ventilation limited) and the heat release rate (fire size) also decreases. This cyclic phenomenon is evident at this particular fire when the smoke layer descends below the level of the crawl space entrance, resulting in limited smoke filling below the crawl space entrance and “cold smoke” throughout the basement. Firefighters noted an elevated smoke layer that was inconsistent with a typical basement fire since both the fuel and the enclosure were elevated relative to the height of the rest of the basement.

Since many CSST fuel lines are routed through elevated structural ceiling void spaces between the basement and first floor, it can be common for CSST fires to present as a fire seated on the first floor, when in reality the fires originated in the basement ceiling and spread through the combustibile structural void spaces located below the first floor where the first visible flames is present. This difference in the presentation of visible burning and the concealed area of fire origin in the basement flooring structure below can create structural collapse issues for crews, as documented in a subsequent LODD event that occurred after 7005 Woodscape Drive. Firefighters observe and attempt to suppress flames on the first floor when in reality the fire originated in the void below and the crews inherently operate over the seat of the fire. In addition, the smoke layer in the basement is typically elevated due to the routing of the CSST along the basement ceiling, which can be easily mistaken for residual smoke from a fire on the first level when in fact the fire is located and should be accessed from the basement level.

The relatively complex fire dynamics associated with elevated fires are rarely taught to the fire service/fire investigation community. Firefighters should consider ensuring that the basement is completely free of smoke and fire, including at the basement ceiling level where CSST may be routed, as part of fire scene size-up operations.

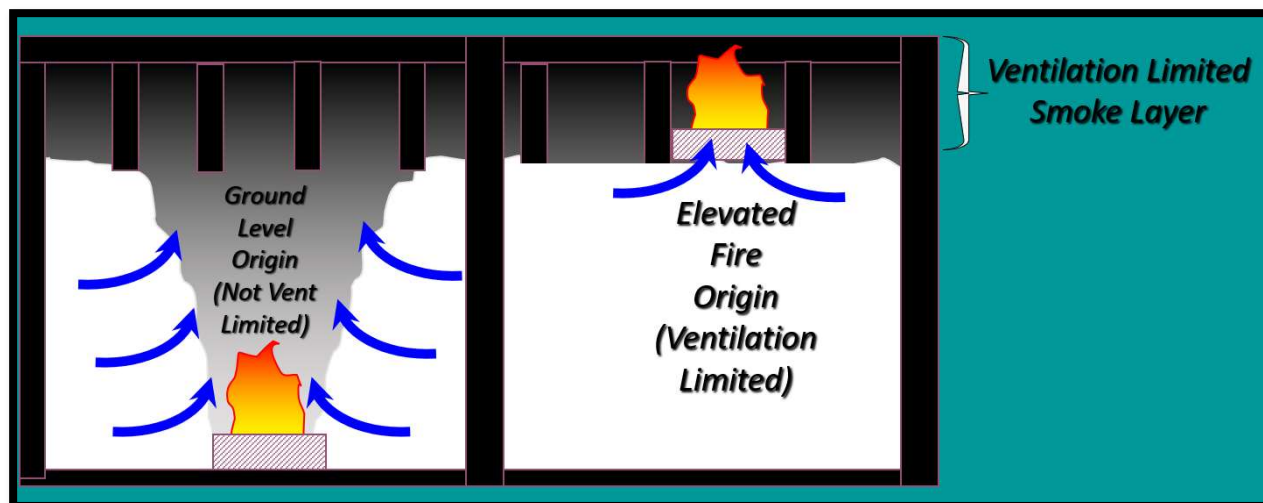
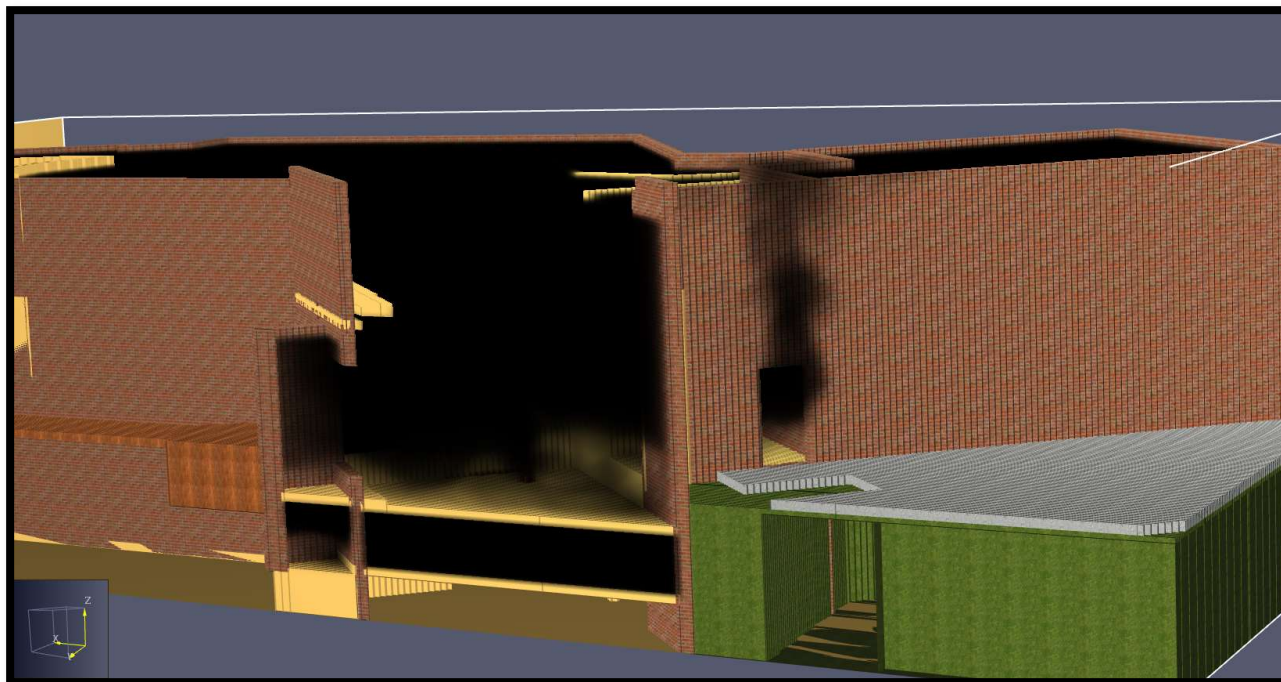


Figure 51. Image comparing the smoke layer development of an elevated fire versus a ground level fire. Fires elevated in height within an enclosure result in unique smoke filling characteristics relative to the larger enclosure. Frequently, ventilation limited conditions occur prior to the smoke layer reaching floor level. Since many CSST gas lines are routed through void spaces between the basement and the first floor, CSST basement fires can initially present as first floor fires, which results in firefighters operating over the seat of the fire and increasing risk of structural collapse.

**3. Ventilation flow path existed from basement door (inlet), through the hole in the crawl space and out first floor mud room door (outlet). This flow path created untenable conditions on the first floor during the MAYDAY:**

The effects of ventilation complicated the effort to locate the well-developed fire in the crawl space during the incident, causing the flames to appear to be located on the first floor (above the crawl space) when both the basement door and mud room door were left open. Firefighters witnessed what they believed to be flames on the first floor and redirected their hoseline to the first floor. Despite the fire burning throughout the crawl space, Firefighter Flynn had multiple visual indications that the seat of the fire was located on the first floor (flames on the first floor, elevated smoke layer in the basement, bi-directional smoke flow initially through mud room door) and he was likely unaware that the burning crawl space was located below him prior to falling into the hole.

The mud room door remained open from the time of the initial 911 call throughout the entire incident. As the fire was located in the crawl space, this ventilation opening had minimal effect on initial fire growth as it was remote from the fire and functioned as both the inlet and outlet as the sole ventilation opening in the house. Noting smoke from the door (bi-directional flow) crews made initial entry through this opening, were unable to locate any flames and recognized indications of a possible basement fire below them and withdrew. Crews then made entry through a basement door located on the lower level of side C.



**Figure 55. The mud room door remained open throughout the incident. As the fire was located completely below the mud room, this ventilation opening had minimal effect on initial fire growth as it was remote from the fire. The opening functioned as both the inlet and outlet prior to the basement door opening.**

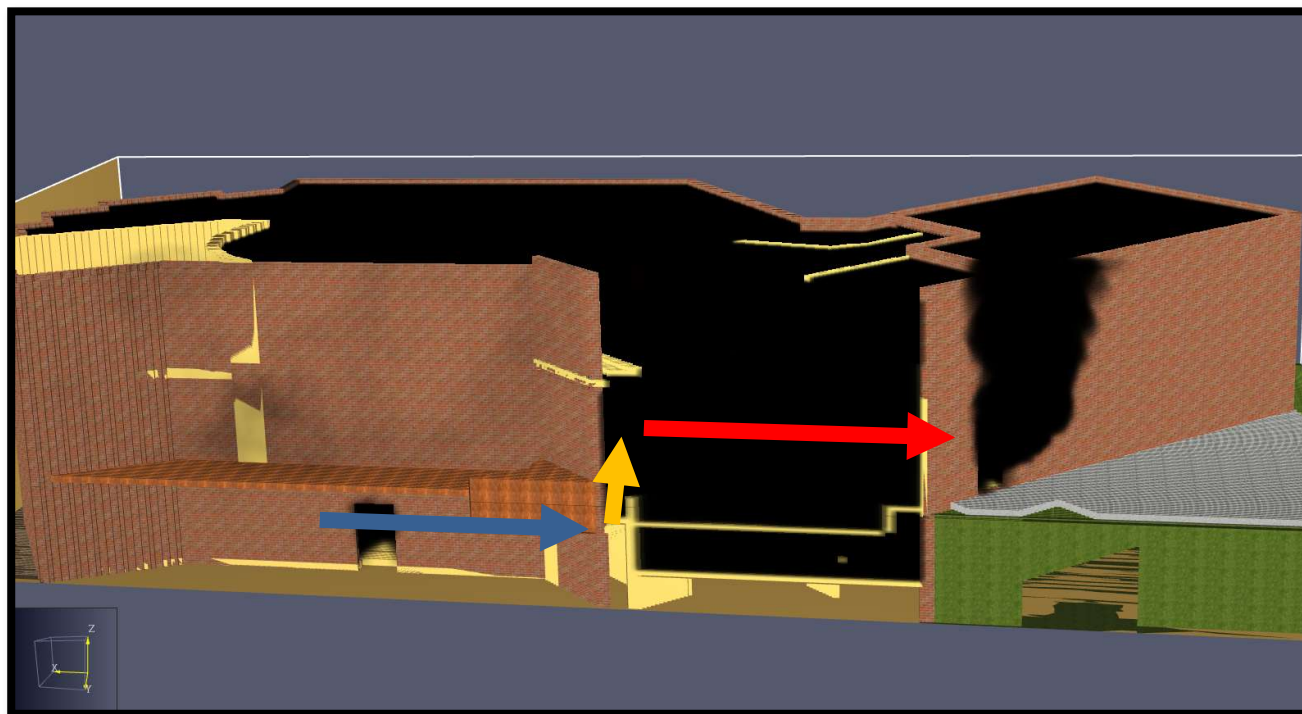
Crews repositioned to the basement door and did not encounter conditions of a typical basement fire, noticing low heat conditions in the basement and an elevated smoke layer (see conclusion point #1). The presence of a concealed crawl space below the dining room was not known by crews. Upon making initial entry into the basement and attempting to locate the fire, the crews were redirected to the first floor as flames were then visible in the area of the living room. In reality, upon opening the basement door, computer modeling and scene photographs indicate a ventilation flow path was created with the basement door as the inlet, the crawl space (and hole in the floor) as the connecting space and the mud room door as the outlet. This rapid increase in fresh air from the basement door to the seat of the fire allowed flames to now become evident through an exterior window on the first floor. Crews then withdrew from the basement and were redirected to the first floor prior to locating the fire in the crawl space.

To complicate the issue, by the time Firefighter Flynn obtained a hoseline and made entry into the first floor through the mud room door, the lower level basement door was shut and there were no longer visible flames on the first floor and no unidirectional flow path at the mudroom door where Firefighter Flynn entered, thus no indication of a basement fire below. Firefighter Flynn then advanced the hoseline into the first floor, believing that the fire was located in the first floor living room. Firefighter Flynn then fell into the burning crawl space below.

Crews briefly attempted to rescue Firefighter Flynn through the hole in the living room. The free-burning crawl space and the fire gases venting up through the hole created untenable conditions for firefighters on the first floor and prevented a successful rescue from above. Firefighters realized they needed to suppress the fire in the crawl space and effect the rescue from the basement level. The RIT members and rescue

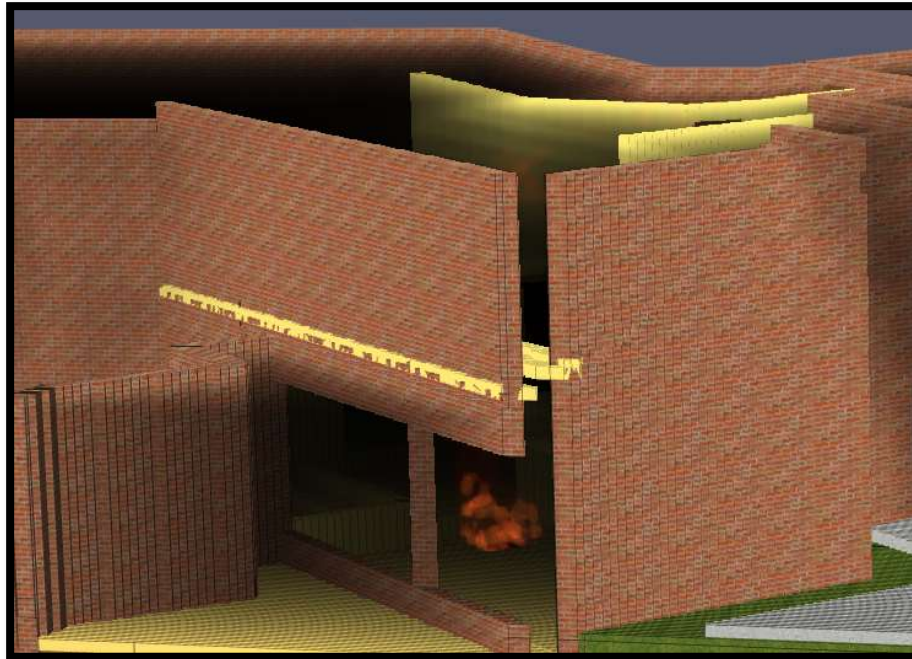


operations occurred from the basement level at-grade entrance on lower side C. High heat conditions existed on the first floor as additional air was supplied to the burning crawl space during the rescue operation. Crews encountered flames throughout the crawl space as they advanced towards the sound of Firefighter Flynn's alarming SCBA. Computer fire modeling indicates high velocity, unidirectional smoke exhausting from the mud room. Crews on scene stated that they believed the mud room was approaching flashover conditions during MAYDAY/RIT operations in the basement. This observation was supported by video captured during the fire.

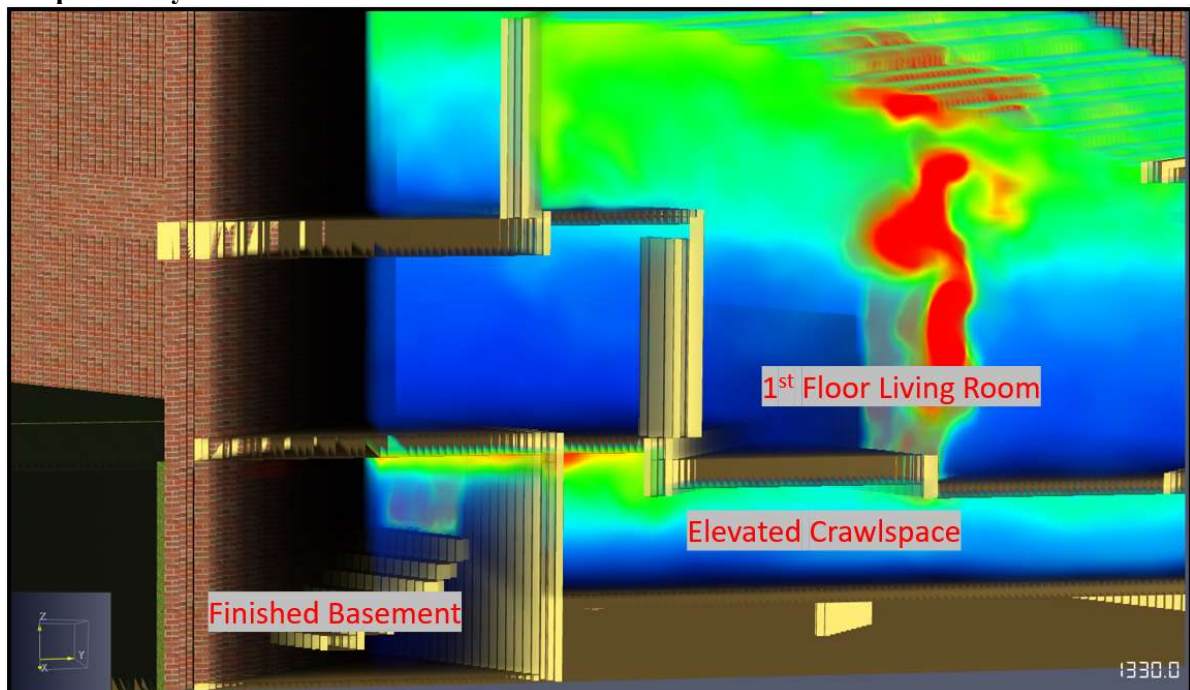


**Figure 56.** The basement door served as a unidirectional inlet, allowing fresh air to reach the fire in the crawl space and exhaust through the mud room door on the first floor. This buoyancy driven gas flow was a function of the height difference between the two openings.

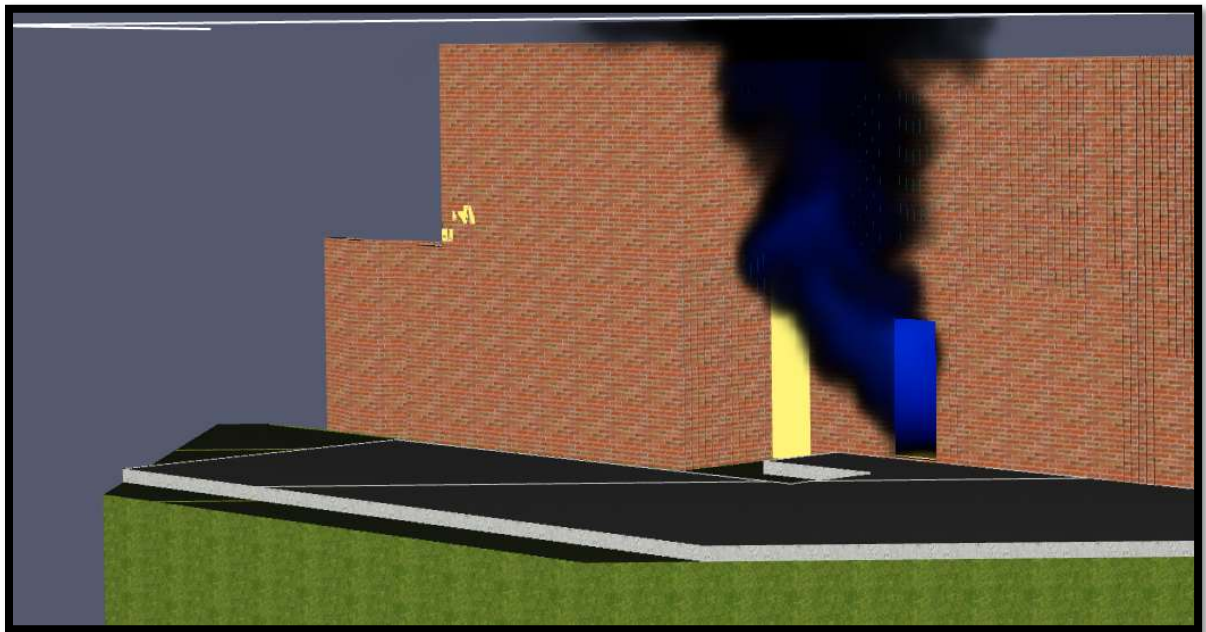




**Figure 57.** This rapid increase in fresh air along the inlet, to the seat of the fire, allowed flames to become visible through an exterior window on the first floor. Once the basement door was again shut as crews repositioned, the fire once again became ventilation limited and the flames were no longer visible from the exterior. Firefighter Flynn fell through the hole and into the burning crawl space when he attempted to locate the previously seen flames on the first floor.



**Figure 58.** Pyrosim Results image depicting high heat conditions through the crawl space, venting to the first floor. The heat energy traveled along the flow path and eventually exhausted through the mud room door.



**Figure 59. Pyrosim Results image depicting unidirectional flow path through the mud room door at the time of the MAYDAY/RIT rescue operation.**



**Figure 60. Photograph of upper level side C (first floor) mud room entrance door captured immediately prior to Firefighter Flynn entering with a charged hoseline after firefighters noticed flames on the first floor from the exterior. Note light smoke and the bi-directional flow out of the mud-room door as the basement door (inlet) was closed at this time. Firefighter Flynn falls into the burning crawl space approximately 2 minutes after this photograph was taken.**



**Figure 61. Photo of the same mud room entrance door captured AFTER Firefighter Flynn entered and falls through the hole into the crawl space. Note the hoseline on the stairs to the first floor landing. This photo was taken during the RIT rescue operation. Note the transition to a unidirectional outlet with dense, high-velocity smoke exhausting from floor to ceiling. The first floor was untenable for firefighters at this point.**

#### **4. Corrugated Stainless Steel Tubing (CSST) location and associated structural collapse:**

The cause of the fire was classified as “Natural” by the investigative team, resulting from a nearby lightning strike to a large tree. Associated energy from the lightning strike followed a path from the tree, through the soil, to a nearby underground propane storage tank. The propane storage tank supplied the residence through an underground copper supply line that transitioned to metallic Corrugated Stainless Steel Tubing (CSST) that ran through the crawl space beneath the living room. Immediately prior to calling a MAYDAY, Firefighter Flynn fell through a hole in the living room into the burning crawl space below. This hole was located in the immediate area of the arc hole found in the CSST gas line.

*NFPA 921: Guide for Fire and Explosion Investigation (2021 Edition)* addresses lightning induced failure of fuel gas system piping: “Lightning can also cause fires by damaging fuel gas systems. Where gas lines are damaged, fuel gas can leak, and the same arcing that caused the gas line to fail may also cause ignition of the fuel gas.”<sup>7</sup> Fuel gas piping, including CSST, is frequently routed through unprotected (unfinished) sections of residential structural flooring or wall cavities as it supplies gas appliances located throughout the residence. Due to the common placement of gas-fueled appliances in the basement level and throughout the first floor, including the kitchen and living room, CSST is most commonly routed through the combustible structural void space between the basement ceiling and the first floor. In the event of a lightning induced CSST failure, sustained ignition of the escaping fuel gas can occur. The location of the gas lines proximal to combustible structural members can support sustained combustion of these members, which can lead to structural compromise and collapse, frequently from the 1<sup>st</sup> floor into the burning basement.



While the floor joists and OSB sheathing supported flame spread and burned-away, the non-combustible tile and tile backing appeared relatively cool on infrared thermal imaging cameras and remained intact despite having compromised structural support below. The relatively massive construction of the flooring system masked the heat signatures one might expect from a fully-involved crawl space fire and a structurally-compromised flooring system below.



**Figure 62. Smoke production through the tile floor with a well-developed fire in the crawl space underneath. The thermally thick (massive) living room floor construction helped mask the well-developed fire underneath firefighting crews operating above.**





**Figure 63. Despite having a fully-involved crawl space and compromised structural integrity, the top of the flooring tiles appeared relatively cool on thermal imaging IR cameras (areas circled in red).**

The collapse risk is compounded by the fact CSST fires can remain concealed in the structural void space above the basement and flames often vent at the first floor level (and not in the basement), causing firefighters to operate over the seat of the fire. There are no reliable indicators of pending structural collapse for firefighters and Firefighter Flynn was unaware of the fire in the crawl space below him.<sup>8</sup> When a lightning strike is suspected, firefighters should gain access and rule-out fire spread in concealed spaces containing combustible structural members on all levels of the structure. Special attention should be paid to the flooring system between the basement and first floor as collapse into the basement is possible if a fire originated in this area.



## **5. Additional Lightning Induced Corrugated Stainless Steel Tubing (CSST) LODD Incident:**



On August 11, 2021, approximately three years after the LODD of Firefighter Nathan Flynn, Captain Joshua Laird (Frederick County Maryland Fire and Rescue) was killed battling a fire in a large residential structure caused by lightning induced failure of CSST routed along the basement ceiling. Captain Laird called a MAYDAY after falling through a hole from the first floor living room into the burning basement below, where the fire originated. Captain Laird saw flames on the first level and was advancing into the living when the collapse occurred. The tiled floor, cement board and wood structural components collapsed and formed a hole above the general location of the CSST gas line in the basement. Multiple lightning induced arc holes were located in the CSST gas line that ran beneath the living room. There are no indications that Captain Laird was aware of the fire burning in the basement at the time when the MAYDAY occurred.

“The source of the Ball Road fire was a lightning-induced failure within the Corrugated Stainless-Steel Tubing (CSST) gas line, running in the void space between the parallel chord trusses supporting the first floor. The fire spread laterally to nearby parallel chord trusses and the subfloor components below the family room in the bravo quadrant of the structure.”<sup>4</sup>

A detailed analysis of the fire development of the Ball Road LODD is outside the scope of this report, however multiple fact-based similarities between these incidents exist and highlight the importance of the conclusions developed in this report. The details about Captain Laird’s LODD incident were sourced from the publicly released “Frederick County After Action Report and Improvement Plan.”<sup>4</sup> The timeframe and common circumstances of both LODD incidents are astonishingly similar and warrant review to prevent future similar incidents. A side-by-side comparison of both LODD incidents is provided below:

### Fact-Based Summary/Comparison of Firefighter Flynn and Captain Laird LODD Incidents

<b>Incident Details</b>	<b>7005 Woodscape Drive, Howard County, MD FF Flynn LODD July 23, 2018<sup>2</sup></b>	<b>9510 Ball Road Frederick County, MD Capt. Laird LODD August 11, 2021<sup>4</sup></b>
<b>Structure Type/Size</b>	Large, Open Single-Family Residence Type V- Wood Construction 8,400 Square Feet Non-Sprinklered 	Large, Open Single-Family Residence Type V- Wood Construction 5,400 Square Feet plus Basement Non-Sprinklered 
<b>Area of Fire Origin</b>	Fire originated in area of unfinished crawl space ceiling. CSST ignited combustible (wood) structural members with flame extension to stored Christmas decorations and other items in crawl space.	Fire originated in area of unfinished basement ceiling. CSST ignited combustible (wood) structural members with flame extension to stored Christmas decorations and other items stored in the basement.
<b>Fire Cause</b>	Lightning strike caused CSST gas line to arc/ignite escaping gas. Extended “pre-burn” time prior to fire dept. arrival with smoke filling all three floors.	Lightning strike caused CSST gas line to arc/ignite escaping gas. Extended “pre-burn” time prior to fire dept. arrival with smoke filling all three floors.
<b>Location of Primary Fire Attack</b>	First visible flames were seen on the 1st floor. Firefighters advanced hoseline on the 1st floor over the burning crawl space. MAYDAY firefighter then fell into the burning crawl space. Firefighters were unaware of fire conditions within the crawl space.	First visible flames were seen on the 1st floor. Firefighters attacked the flames on the 1st floor from the exterior and transitioned inside. MAYDAY firefighter then fell into the burning basement after making entry to the 1st floor. Firefighters were unaware of fire conditions within the basement.

<p><b>MAYDAY Location</b></p>	<p>While attempting to suppress the 1st floor fire, MAYDAY firefighter falls through 1st floor into burning crawl space below. Firefighter immediately calls MAYDAY. Multiple layers of thick tile/cement board at hole location. CSST flame consumed combustible structural members below the hole location.</p> 	<p>While attempting to suppress the 1st floor fire, MAYDAY firefighter falls through 1st floor into the burning basement below. Firefighter immediately calls MAYDAY. Multiple layers of thick tile/cement board at hole location. CSST flame consumed combustible structural members below hole location.</p> 
<p><b>Initial MAYDAY Rescue Efforts</b></p>	<p>Crews immediately respond to MAYDAY and attempted to rescue MAYDAY firefighter through the hole from the 1<sup>st</sup> floor. Heat and smoke from unsuppressed crawl space fire below prevented rescue from above. RIT crews repositioned to basement grade entrance to successfully suppress fire and rescue MAYDAY firefighter.</p>	<p>Crews immediately respond to MAYDAY and attempted to rescue MAYDAY firefighter through the hole from the 1<sup>st</sup> floor. Heat and smoke from unsuppressed basement fire below prevented rescue from above. RIT crews repositioned to basement stair entrance and rescued MAYDAY firefighter.</p>
<p><b>RIT Firefighter Removal</b></p>	<p>RIT suppressed fire in crawl space and successfully extricated MAYDAY firefighter through the basement at-grade entrance point.</p>	<p>RIT successfully extricated MAYDAY firefighter through the basement at-grade entrance point.</p>

## ACKNOWLEDGEMENTS

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First and foremost, the efforts of Celeste Flynn and Sara Laird to support this research and share as much information as possible about these tragic LODD events in an effort to prevent future similar tragedies deserves to be recognized. Thank you, Celeste and Sara.

This investigative analysis report is the culmination of a team effort involving both ATF and our state and local counterparts, who assisted with fire scene processing, fire testing, and reviewed the content of this report.

The following individuals deserve recognition for their support of this project:

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- Gordon Wallace, Assistant Chief, Howard County Department of Fire and Rescue Services
- Thomas Coe, Chief, Frederick County Department of Fire and Rescue Services
- Troy Grossnickle, Captain, Frederick County Department of Fire and Rescue Services
- Eddie Ruch, Lieutenant, Frederick County Department of Fire and Rescue Services
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- Jeremy Neagle P.E., Electrical Engineer, ATF Fire Research Laboratory
- Juan Rosado-Marin, Electrical Engineer, ATF Fire Research Laboratory
- Michael Abraham P.E., Electrical Engineer, ATF Fire Research Laboratory
- Charles Giblin III P.E., Fire Research Engineer, ATF Fire Research Laboratory
- Benjamin Rouleau, P.E., Fire Research Engineer/Electrical Engineer, ATF Fire Research Laboratory
- Jason Ouellette, Laboratory Section Chief, ATF Fire Research Laboratory
- John Allen P.E., Chief, ATF Fire Research Laboratory
- James Zurenko, Laboratory Technician, ATF Fire Research Laboratory
- Steven Little Sr, Laboratory Technician, ATF Fire Research Laboratory
- Steven Little Jr., Laboratory Technician, ATF Fire Research Laboratory
- Dennys Hernandez, Laboratory Technician, ATF Fire Research Laboratory
- Dr. Daniel Madrzykowski, Senior Director of Research, UL Fire Safety Research Institute
- Keith Stakes, Research Engineer, UL Fire Safety Research Institute
- Lisa Herb, Senior Special Agent/Certified Fire Investigator, ATF Baltimore Field Division
- Daniel Giblin, Special Agent/Certified Fire Investigator, ATF Baltimore Field Division
- Brian Mayers, ATF Task Force Officer, ATF Baltimore Field Division
- Michael Eldredge, ATF Explosives Enforcement Officer, ATF Baltimore Field Division
- Derek Chapman, Deputy Chief, Maryland State Police, Office of the State Fire Marshal
- Michael Selvedge, Senior Deputy, Maryland State Police, Office of the State Fire Marshal
- Brian Quick, Senior Deputy, Maryland State Police, Office of the State Fire Marshal
- Melissa Decker, Senior Deputy, Maryland State Police, Office of the State Fire Marshal
- Peter Raia, Deputy, Maryland State Police, Office of the State Fire Marshal



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